

962
Elements of Chemistry :

BEING THE
ANNUAL LECTURES
OF

Herman Boerhaave, M.D.

Formerly PROFESSOR of
CHEMISTRY and BOTANY,

And at present,

PROFESSOR of PHYSICK
IN THE
UNIVERSITY of LEYDEN.

Translated from the ORIGINAL *LATIN*,

By *TIMOTHY DALLOWE, M.D.*

VOL. I.



L O N D O N:

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THE
TRANSLATOR
TO THE
READER.

AS the Reader, in this Translation, may observe several Variations from the Original, it is necessary to inform him that the Alterations are made with the Author's Approbation. I am very sensible that, upon the whole, I shall be challenged for following the Original too minutely: but I was willing rather to err on this hand, than to leave out any thing, that might have a Meaning and Propriety that I was not aware of. It must be confessed however, that our Author is evidently, in many places, pretty prolix; nor in reality, considering these as Publick Lectures, could this possibly be avoided: For as we had nothing to depend upon but our Memories, and the short Hints we could take in Writing from the Professor's Mouth, it was necessary for him to dwell longer upon Things, and set them in various Lights, in order to make them appear with more Evidence, and fix them upon the Mind with greater Certainty. It were to be wished, indeed, that when he came to printing them, he had had Time sufficient for retrenching these Superfluities; but I have a great deal of Reason to think this was not the case; and yet he was under a kind of Necessity of putting them out as soon

To the READER.

as possible, to justify himself from the monstrous Absurdities published in a Course of Chemistry with his Name to it, which some of his Pupils ungenerously printed without his Knowledge, as you will find taken notice of in the Preface. Had this Work, at first, been designed purely for the Press, or had the Author had Leisure to have put a finishing Hand to it in the Form it stands at present, it would, without dispute, have appeared much more to Advantage, both in point of Elegance, and Correctness. As the Substance of the Performance, however, is still the same, and it contains abundance of curious and valuable Observations and Experiments, both in Chemistry, and Natural Philosophy, the Reader no doubt will readily overlook any Inaccuracies he may meet with, and think himself obliged to the worthy Author, who has so candidly communicated the Result of many Years indefatigable Application.

T. Dallowe.

London
1 March 1734-5.

T H E

THE
AUTHOR'S DEDICATION

To his BROTHER

JAMES BOERHAAVE.

AS I could not avoid publishing the Work which I now address to you, I have been obliged in my old Age to review the Labours of my Youth. And whilst I have been thus engag'd, I could not help, I confess, being sometimes surpriz'd, when I consider'd both the number of them, and the remarkable Dangers that frequently attended them. The grateful Reflection, however, of your having been my constant faithful Companion and Partner in both, gave me at the same time a very sensible Satisfaction. You know very well, nor is the Remembrance, I flatter myself, disagreeable, how many whole Days and Nights we have spent successively together in the chemical Examination of Natural Bodies. At that time, indeed, your Thoughts were turned chiefly to Physick, mine to Divinity: But Providence ordered otherwise; so that altering our Designs, you devoted yourself intirely to Sacred Things, making it your whole Concern to promote the true Worship of God, by the Plainness of your Preaching, and the Integrity of your Life; whilst I, conscious of my weaker Abilities, and not daring to attempt any thing higher, was content to apply myself to the Study of the Healing Art.

Who,

The DEDICATION.

Who, therefore, has an equal Right to this Work with yourself, to whom it in some measure owes its being what it is? Accept it, therefore, I entreat you, with the same kind Resentments, with which I offer it; and let it stand as a publick Token of a grateful Acknowledgment, and a lasting Memorial of Fraternal Affection. I have always esteem'd it my particular good Fortune to be favoured with such a Brother, whose happy Genius, and vertuous manner of Life, render him not unworthy of that great Office he is entrusted with, the noble End of which is purely to recommend the Terms of Reconciliation, offered by God to Mankind, by Precept and Example, without a vain Affectation of any thing more. If in my Province, I have been so happy likewise to behave in such a manner, as to meet with your Approbation, I shall have wherein to rejoice. Adieu; and whilst you are now and then amusing yourself with Things of this Nature, don't forget those joint-labours we were formerly so agreeably engaged in.

Leyden, 1. July 1731.

T H E

T H E
A U T H O R'S
P R E F A C E.

NOTHING was formerly farther from my Thoughts, than that I should ever trouble the World with any thing in Chemistry. There are so many Books already upon this Subject, and many of them wrote so well, that it is hardly possible for me, either to represent things in a better Light, or to offer any thing that has not been said before. My Academical Office however made it necessary, that I should annually give a Course of Lectures in this Art; but this was with no other View, than just to lay down the Rudiments of it, and give some Examples of the Operations, for the sake of those Gentlemen, who were pleased to put themselves under my Tuition. And so far it is possible, the Method I have made use of in digesting the Subject, and the great Simplicity I have constantly and carefully studied, may not have been without their use. And in these two Particulars, indeed, there seemed still some room left for farther Application; that at last Chemistry too might deserve to be introduced among the Academical Sciences. This, therefore, I endeavoured to the best of my Abilities; and having done this, I thought I had discharged my Duty, and that nothing farther could reasonably be expected from me. It has happened, however, very different from what I was aware of: For the Ingratitude of some of my Pupils, the promoting whose Interest was always my Study; and the insatiable Avarice of some Booksellers, who will not stick at the basest Actions, if they can make any Advantage of them, sufficiently sowed my Chemistry-Professorship. For these Persons, under a false pretence of doing Service to Learning, published, without my Knowledge, a Course of Chemical Institutions and Experiments, and prefixed my Name

THE AUTHOR'S PREFACE.

to it; and thus did an Injury both to the Publick and me, in a manner certainly very dishonourable, and that ought to be taken notice of by the Laws. The false Notions, Absurdities, and Barbarisms, that are imputed to me in every Page of that Work, are so abominable, that they will not bear mentioning. It happened, however, to the Misfortune of the present Age, of which by this means they have left an instance to the succeeding, that this sorry Book met with too many Buyers, very much to the Loss and Disgrace both of them, and the Persons who recommended it. By this means I had the daily Mortification of seeing my Pupils before me with this Book in their Hands, whilst I was giving my Lectures; and could plainly perceive, that every Word I said must be examined by the Text of that miserable Performance. Quite tired with this, I applied myself for Relief to some Persons in Authority, who had Power to restrain and punish such Enormities as these; and I had almost gained my point, had not some others designedly delay'd, put off, nay and opposed it too, though I had deserved much better things at their Hands, and had received from them so many fair Promises in my favour, as, I think, would have deceived the most cautious Man living. Thus then I was satisfied by an uncomfortable Experiment, that there are some Persons in the World, who take Pleasure in triumphing over Learning, by every method that lies in their Power. These, and other Considerations, determin'd me to give Lectures in Chemistry no longer; and therefore I immediately resigned my Professorship. But this was no sooner over, than I was again engaged in new Difficulties; for my Friends were all of opinion, that in my own Defence I ought to publish my Chemical Institutions and Experiments myself, that by this Means the World might have an Opportunity of judging in what manner I did in reality teach Chemistry, both in the publick and private Schools. It was to no Purpose for me to object, that these Institutions were designed only for my private Use, and calculated purely for Beginners, to lay before them the first Elements of the History and Method of Chemistry, and of consequence would be of no manner of Service to the Publick. Nay I insisted farther, that as these only laid down the Rudiments of the Chemical Art, and had nothing else to recommend them, they must necessarily be disagreeable to any Reader that was ever so little versed in it. They on the other hand urged, that the spurious Work met with general Approbation, was mightily wanted, grew dearer, and would be very soon reprinted, if I did not take care to prevent it. This I confess gave me some Uneasiness, and brought to my Mind the great Petrarch, who lamented the Misfortune of his Contemporaries, when he saw them set such a value upon his Works, as to think him worthy to be rank'd amongst the famous Poets. How much more then, thought I, ought I to be ashamed, should I, who am conscious of my own poor Abilities, and am an Admirer of other Authors, dare to intrude myself
among

among the Chemical Writers. Not able, however, to stand out any longer, I at last undertook the disagreeable Task; and I publicly declare, that the Book with which I now trouble the World, was forced from me much against my Inclination. As for the Work, I have wrote it in as concise a manner as the Subject would admit of; and have avoided as much as possible pure Terms of Art. That this might be done, I saw evidently in the Example of the incomparable George Agricola, in that immortal Work, *De Fossilibus, Re Metallica, & Subterraneis*. I heartily wish, indeed, I had had so much Time at command whilst I was composing this Treatise, as was necessary for the sufficient Imitation of so great an Author. For want of this, and being hurried with a Variety of Business whilst this large Work was in Hand, I am sensible, many Expressions have escaped me, that are not so elegant. I am aware too, that some Persons will think I very often insist too particularly upon things that seem but of little Consequence: But this I have done with Design, on purpose to caution sufficiently against those Inconveniencies, that in these kind of Inquiries continually surround us. I have constantly had Beginners in my view; and therefore thought myself obliged to point out every thing doubtful, or dangerous. For the same reason you'll find I every where proceed chiefly upon particular Experiments, not laying down any general Rules, without a great deal of Caution. By this Example, young People may learn the Method that Beginners should pursue in their philosophical Inquiries; a laborious one, I confess, but certainly a just one, and that will lead us most securely to true Knowledge. In the first part of this Work I had those Lectures to insert, which I had given at particular times upon Chemical Subjects in the publick Schools: And as I thought it necessary to relate them again, and confirm them by new Observations, it has happened, that I have sometimes repeated things I had said before; which it was not possible to avoid. And thus the Size of the Book insensibly grew upon my Hands, though at the same Time I was too much engaged in Business of another Nature. How happy, under these Difficulties, did I count those Authors, who have Time enough to study, digest, and put a finishing Hand to the Works they are employed in. For my part, amidst a thousand Avocations, I have been obliged to dispatch these things in a rude manner, and very different from what I should have done, had I been Master of that Leisure and Retirement which I have long wished for: Especially, as I have a great Desire to confirm and improve some particular Parts by new Experiments. Those which are now contained in this Work, are what I made in publick many Years ago: And this I think proper to mention, lest any body should suspect I borrowed them elsewhere, without making mention of the Author's Name. But to detain my Reader no longer, please to accept this Performance, such as it is, in a favourable manner; excuse the

a

Trouble

THE AUTHOR'S PREFACE.

Trouble I by this means give you; and impute the Liberty I take of appearing in Print upon this Subject, to the very good Reception the spurious Copy, which was worse, met with from the Publick. Upon this Occasion, too, give me leave to inform you, that I never published any thing besides what follows; which I confess I am ashamed to mention.

Oratio de commendando Studio Hyppocratico. Spoken and printed at Leyden 1701; for Abrah. Elsevier.

— *de Usu Ratiocinii Mechanici in Medicina, 1703, for John Verbeffel.*

— *quâ repurgatæ Medicinæ facilis afferitur Simplicitas, 1709, for John Vander Linden.*

— *de comparando certo in Phycis, 1715, for Peter Vander Aa.*

— *de Chemia suos errores expurgante, 1718, for Peter Vander Aa.*

— *de Vita, & Obitu Clarissimi Bernardi Albini, 1721, for Peter Vander Aa.*

— *de Honore Medici Servitute, 1731, for Isaac Severinus.*

An Oration, which I delivered when the Curators of the University honourably gave me leave to resign my Professorships of Botany and Chemistry, 1729, for Isaac Severinus.

Institutiones Medicæ in Usus annuæ exercitationis domesticæ, 1708, for John Vander Linden, Father and Son.

Which was afterwards reprinted several times, with Additions in 8vo.

Aphorismi de Cognoscendis, & Curandis Morbis in usum Doctrinæ Domesticæ, 1709, for John Vander Linden.

Of which there were afterwards several Editions, with Additions, in 8vo.

Index Plantarum, quæ in Horto Academico Lugduno-Batavo reperiuntur, 1710, for Cornelius Boutestein, in 8vo.

Materia

THE AUTHOR'S PREFACE.

ix

Materia Medica, & Remediorum formulæ, 1719, for Isaac Severinus, in 8vo.

Afterwards reprinted in 8vo.

Index alter Plantarum, quæ in Horto Academico Lugduno-Batavo aluntur, 1720, for Peter Vander Aa, in 4to.

Atrocis nec descripti prius morbi Historia, secundum Medicæ artis leges conscripta, 1724, for Boutestein, in 8vo.

Atrocis rarissimique morbi Historia altera for Samuel Luchtmans, and Theodore Haak in 8vo.

A medicinal Treatise de Lue Venerea, prefixed to the Collection of Authors upon the Venereal Disease, 1728, for John Arn. Langer, and John and Herm. Verbeek, in Folio.

Epistola pro sententiâ Malpighianâ de Glandulis ad Clariss. Ryiscium, 4to for Peter Vander Aa.

Every thing else printed in my Name, except a few Prefaces, is spurious, and published without my Knowledge.

A VIEW

A VIEW of the CHAPTERS into which this Volume is divided.

THE Design	Page 1	Of Fire generated in a cold Body by the sole	
PART I.		Accels of the Air	222
The History of the Art	4	Of Fire produced from cold Fossils by the	
PART II.		help of Water	225
The Theory of the Art	19	Of Fire generated by the Mixture of cold	
Of Metals	19	Liquors	226
Of Salts	27	Of Air	247
Of Sulphurs	29	Of Water	317
Of Stones	32	Of Earth	364
Of Semi-Metals	33	Of Chemical <i>Menstruums</i>	386
Of Vegetables	36	Of Water and Aqueous <i>Menstruums</i>	415
Of Animals	40	Of Oils and Oily <i>Menstruums</i>	427
Of the Use of the Art in Physicks	50	Of Spirituous <i>Menstruums</i> or Alcohol	436
Its Use in Medicine	52	Of Spirituous, Alcaline, and Acid <i>Menstruums</i>	438
in the Mechanic Arts	56		438
Of the Instruments of Chemistry	78	Of Simple Saline <i>Menstruums</i>	440
Of Fire	78	Of a fixed Alkali, as a <i>Menstruum</i>	462
Of the <i>Pabulum</i> of Fire	168	Of Acid <i>Menstruums</i>	472
in Animals	208	Of Neutral Salts as <i>Menstruums</i>	489
in Fossils	208	Of the Universal <i>Menstruum</i> , or Alcahest	
Of the Heat arising from the Mixture of		Of Chemical Vessels, and the Furniture of a	
Animal and Vegetable Substances	220	Laboratory	500
Of the Heat arising from the mixture of		Of Lutes.	507
Fossils	221	Of Furnaces	508

ERRATA.

PAGE 2. Line 7. read Historians. P. 3. l. 13. r. call Processes indeed, P. 4. l. 9. from the bottom, r. the Story. P. 5. l. penult. r. Art seems by its. P. 19. l. 21. r. Name. P. 22. l. 16. from the bottom, r. yellow ones. P. 24. l. 25. r. and then rubbing. Ibid. l. 4. from the bottom, r. where it adheres. P. 25. l. 3. r. 3. Too distinguishes. P. 30. l. 7. r. by Fire, P. 31. l. 18. Naphtha. P. 44. l. 10. from the bottom, r. in direction. P. 46. l. 29. r. exceeding fine Elements. P. 48. l. 6. from the bottom, r. but little, P. 49. l. 1. r. this noble vertue. P. 54. l. 8. from the bottom, r. in the middle. P. 58. l. antepenult. r. and when it does. P. 61. l. 8. from the bottom, r. need not say much. Ibid. l. 7. from the bottom, r. John Rudolphus Glauber. P. 62. l. 23. r. Ore. Ibid. l. 7. from the bottom, r. from the Cupel. P. 68. l. 17. from the bottom, r. those of us. P. 78. l. 28. r. Laboratory, and so always where that word occurs. P. 82. l. 25. r. warmer in the former, and colder in the latter. P. 88. l. 9. r. and then, possibly, it is not. P. 89. l. 9. from the bottom, r. and of course will take. Ibid. l. 8. from the bottom, r. the best Clocks. P. 91. l. 12. r. there arises. P. 99. l. 6. r. means, then, upon. P. 110. l. 3. r. thus dense. P. 111. l. 6. r. then the Mercury. P. 128. l. 13. r. sleeping. Ibid. l. 14. r. horizontally. P. 132. l. 10. from the bottom, r. relief to the head. P. 133. l. 14. r. always decreases. P. 144. l. 5. from the bottom, r. good deal of expence. P. 144. Margin, r. determining. P. 158. l. 21. r. grow equally hot. P. 178. l. 7. r. any thing that is. P. 187. l. 18. r. is istire. P. 200. l. 18. mere Flame. P. 206. l. 5. from the bottom, r. to be so pressed. P. 212. l. 19. r. the three additional. P. 216. l. 5. from the bottom, r. and are at rest. P. 217. l. 21. r. with distilled Vinegar. P. 220. l. 18. r. Experi-

ment I. after various manners. P. 224. l. ult. r. their parts. P. 225. l. 30. r. thus produce. P. 243. l. 26. r. are dried and changed into a very black Coal, and if they are calcined are all. P. 248. l. 18. r. exceeding simple. Ibid. l. 20. r. this species. P. 251. Margin, r. Mutual Attraction. P. 254. l. 12. r. by the Air. Ibid. l. 4. from the bottom, r. within the tenth. P. 259. l. 8. r. all other Fluids. P. 260. l. ult. r. incompressible particles. P. 261. l. 14. from the bottom, r. hermetically seal'd. P. 265. l. 8. from the bottom, r. application of Heat. P. 273. l. 17. r. but in the Summer. P. 293. l. 22. r. into spaces reciprocally proportional. P. 296. l. 8. from the bottom, r. rise in the Tubes. Antepenult. r. These things. P. 298. l. 21. r. Torricellian Vacuum. P. 303. l. 19. r. It is boil'd. P. 334. l. 21. r. in Water. P. 342. l. 26. r. into Chalk. P. 362. l. 8. r. Hygroscopes. P. 364. l. 12. from the bottom, r. to the Fossil one. P. 372. l. 10. from the bottom, r. their vast subtlety. P. 379. l. 7. r. ; tho' this I confess. P. 385. l. 8. from the bottom, r. seal'd Earths. P. 386. l. 12. r. I could not well omit. P. 388. l. 7. from the bottom, r. But by this admixture. P. 391. l. 8. from the bottom, r. among them an intire. P. 407. l. 6. r. the Fire. P. 420. l. 21. r. fix'd and volatile Alkali's. P. 424. l. 8. from the bottom, r. Aliments of Animals. P. 434. l. 9. r. But these Oils. P. 436. l. penult. these things. P. 441. l. 1. r. acid, and thus. P. 444. l. ult. r. alkaline Salt. P. 454. l. 12. from the bottom, r. into these. P. 456. l. 1. r. compound Salts. Ibid. l. 6. from the bottom, r. Mindereri. P. 460. l. 14. r. almost like Wax. P. 467. l. 32. r. affusion. P. 468. l. 4. r. affusion. P. 471. Note, r. 9 grains; and add. P. 481. l. 5. from the bottom, r. hence new appearances. P. 484. l. 16. from the bottom, r. Alcohol upon this. P. 494. l. 1. r. two hours, converts.

THE DESIGN.

GENTLEMEN,

AS you have put your selves under my care, to instruct you in the know-
ledge of Chemistry, I shall think it my duty to endeavour as much
as possible to answer your expectations. The Design.

And in this, as far as I can judge, I shall most effectually succeed, if I clearly and methodically explain to you every thing you will have occasion for, either to understand the most valuable Authors, in this Art, from whom you may gain a knowledge of it purely as it stands founded upon Experiments; or, to enable you to perform the principal operations in Chemistry; that by this means you may be ready in the exercise of the Art, as well as thoroughly understand it.

This, however, is not so easy to accomplish, in an Art cultivated by men taught rather by accidental discoveries, than acting according to rules of Art, and who for the most part wanted intirely the knowledge and assistance of the more liberal Sciences. Difficulty of the Design.

For hence it came to pass, that they have given us only a confused collection of the things they observed, just in the order they happened, without any regard to a methodical disposition of them.

And this difficulty was still farther increased, by an almost constant neglect of those things which came very frequently under their observation: for these they did not think worth taking notice of; and yet without them, to a reader not versed in the Art, the causes of many things must be unintelligible.

But then this Science became most perplexed, when these Artists began to introduce their disputations into it; came to coining their general principles; and went about to explain the causes of the different appearances they met with.

These difficulties however may in some measure be removed, by collecting together the genuine Experiments, which have been performed in this Art; from thence deducing some general rules; and then disposing those rules the most to advantage.

Especially, if the person who sets about it, has the happiness of having his mind formed to the work, by a long and careful exercise in the practical part of the Art; which I hope without vanity I may lay a small claim to. Method proposed.

With some hopes therefore of success I undertake writing these Institutions; which I shall divide into three parts. Distribution of the work.

The first of which will contain the rise, progress, culture, and fate of Chemistry; will give an account of the principal Authors in this Art, according to the times in which they lived, briefly hinting at the things in which they agreed, Part the first.

B

and

and wherein they differed; and hence will make mention of the different sects, and what they have contributed towards the advantage or prejudice of the Art: And here (which caution may be of service for guiding your conduct in this Science) giving to every one the glory due to their merit, I shall candidly commend those who on account of their services to the Art distinguish themselves above the rest; and through the whole shall carefully proceed according to those rules, and with that integrity, which Histories ought religiously to observe.

Second part.

The second part will lay down certain, indisputable, chemical Positions, collected from such evident physical truths, as have been discovered by the Chemists; and these will be chiefly of a general nature, and so contrived, that by the help of them may be performed all the operations, that truly belong to the chemical Art.

Theory of Chemistry, what?

Nor indeed in this Art do we allow of any other Theory, than what is built upon such general Propositions, as have first been deduced from many common undoubted Chemical Experiments, from which, as they always succeed in the same manner, some general truth may be fairly inferred.

Limits of this Chemical Theory.

We must take care, however, not to carry even this rule any farther, than simply to apply it to such particular bodies, as we evidently discover to be perfectly of the same nature.

The reason of this cautious proceeding.

For it is certain, that the powers of some particular bodies, frequently produce such effects, as could not possibly have been foreseen from any general Theorem, in as much as they depend purely upon the peculiar nature of those bodies, which perhaps may be different from all others.

Physico-Mathematics, and Physics made use of in Chemistry.

We shall farther, in forming this Theory, take the liberty to make use of such truths, as are demonstrated in Physics, Mechanics, Hydrostatics, and Hydraulics; since the properties, which belong to all bodies in common, must hold good in chemical ones too: but then, we must in this affair proceed with a great deal of caution; as we find, that by the application of some particular bodies to one another, from the singular nature of those bodies effects are often produced, that are quite contrary to the demonstrations which are true of bodies in general. An instance will make this plain: *Galileo* has ingeniously demonstrated the law by which a body will descend from a fixed point above to a point on the earth perpendicularly under it, supposing it to move in a spiral, or elliptical line, and with a certain degree of acceleration. Let us now only imagine the falling body to be a loadstone, and another to be so disposed, that the former in its descent shall come within the sphere of its activity; and then his Demonstration will appear to be false. In like manner, the things which *Archimedes* has proved in his Hydrostatics, though they are strictly true when applied to bodies in general, yet do not always hold so, when applied to particular ones; as we see that gold, which sinks in all other fluids, is dissolved, and suspended in so light a one as *Aqua regia*.

Under these limitations then, the truths discovered by the Philosophers, and others abovementioned, will always be of service to this Art; nor can ever possibly do it any prejudice.

The last part of the Design.

In the third and last part of these Institutions, I shall actually exhibit to your view the methods made use of in Chemistry, in order to change natural bodies in such a manner as this Art directs, and to the end which it likewise had before determined.

And

The DESIGN.

3

And here I shall take care, that the most common things, if it is of any consequence to know them, shall not be omitted; nothing shall be unnecessarily repeated; and that, shall be always treated of first, of which there will be occasion in the process that follows.

The order
in which the
chemical
Operations
are digested.

In the prosecution of which, the Theorems explained in the second part, will be made great use of; by the help of which all the operations in Chemistry will be easily understood, and both the head and the hand fitted for the exercise of the Art: At the same time also, every one of these Processes will be a Demonstration of the truth of the particulars, from which the general Theorem was at first constructed. By this method, Gentlemen, I propose to lead you into the most perfect knowledge of Chemistry; nor have I loaded with difficulties a Science, which in its own nature is sufficiently troublesome. Without this, all the labours of the Chemists, which they call Processes, indeed are of no real service, but waste our time, and instead of being an advantage, are really a prejudice to those that are fond of them.

The use of
the chemi-
cal Theory
in the Ope-
rations.

B 2

COURSE

COURSE of CHEMISTRY.

PART I.

The History of the ART.

The name
of the Art.

THE word, which in the Greek Language signifies *Chemistry*, is *Χημία*, or *Χημεία*: and this is of so very ancient a date, that it is supposed to have been in use before the flood.

This certainly was the opinion of *Zosimus the Panopolitan*, whose Greek manuscripts, which *George Agricola* had seen in the year 1550, and *Joseph Scaliger*, and *Olaus Borrichius* perused afterwards in the King of France's Library, have a remarkable passage in confirmation of it.

For in the book intitled *χεῖσις Ζωσίμου τῆ πανοπολίτις φιλοσόφου ἐκ τῆ πρὸς Θεοσίβειαν ἐν τῇ θ τῆς ἑκτῆς βίβλου*, he expressly says, that the Art which was revealed to the daughters of men by Dæmons, as an acknowledgment of their favours, (*χημίαν καλεῖσθαι*) was called *Chemistry*: For this is the sense of the text, as it was read by *Joseph Scaliger*, and inserted by him in his notes upon *Eusebius*, p. 243, 258. N. 38; And by *Borrichius* against *Conringius*, p. 49. *The sacred Writings tell us, that there is a sort of Dæmons that are familiar with women. And Hermes mentions the same thing in his Physics; and almost all our learning both open and occult, take notice of it likewise. This then the ancient and sacred Scriptures inform us, that the Angels were enamoured of women, and came and taught them all the Works of Nature. Now the first tradition they gave concerning these Arts was called ΧΗΜΑ; and the book likewise that contained it, they called ΧΗΜΑ; and hence also the Art obtained the name ΧΗΜΙΑ. Now this very ancient fiction arose from the misunderstanding those words of Moses, Gen. vi. 2. for from this passage they concluded, that by the sons of God were meant Dæmons, consisting of a spiritual part, and a corporeal one, that was visible only, like the image or phantom reflected from a looking-glass; that these beings were endued with a universal knowledge, were conversant with men, were very fond of women, were great with them, revealed secrets, and appeared to mankind. Compare with this, Luke xxiv. 37, 39. Matt. xiv. 26. And this fable probably gave rise to this story of Σίβυλλα, (Σιβ, that is in the Æolic Dialect, Διδύλλα, or Βελλή,) on whom *Phæbus* in return for her favours conferred the gift of Divination, so that she could discover the will and counsels of the Gods. Thus is the mind of man, whilst in a state of uncertainty, apt to run into very strange conceits, which it afterwards idolizes and regards with veneration.*

But farther, the land of *Egypt* was likewise very anciently called by the same name as *Plutarch* observes, (*Is. & Osir. p. 364. C.*) Besides, the soil of *Egypt* being of an exceeding black colour, like the black of the eye, they call it ΧΗΜΙΑ. And the same country went also by the name, ἐρμoxήμιος, as *Steph. Byzant.* takes notice

tice under the word *ἀγνῶστος*. But the word *χημᾶ* too, as *Bochart* informs us, among the *Arabians* signifies to *hide*.

If we now lay all these things carefully together, we may easily perceive that this name was made use of before the flood; that it continued in use in the succeeding ages; and that in those days it signified,

1. A knowledge of the works of nature, *διδασκαλίαν πάντων τῶν φύσεως ἔργων*. The meaning of this very old name.
2. A book containing the Tradition of such a Science.
3. That *Hermes* in his book of Physics had made mention of it.

The word now, if it is wrote *χημᾶ*, according to *Bochart* signifies to *hide*, as we took notice just now: And hence if *χημία*, as *Plutarch* will have it, (*de Is. & Os.* p. 364. C.) expresses the black of the eye, or any thing exceeding black, there will be no great difference betwixt them, as used by the hieroglyphical writers; for among them the pupil of the eye denotes something hidden, and precious.

Especially, if we consider that the same *Egypt*, called in the sacred Writings the land of *Cham*, (*Psalms* cv.) stiled their God *Ἀμῶν*; which according to *Manetho* the *Sebennite* signifies somewhat concealed. *Plut. de Is. & Os.* p. 354. C.

Nay, and that the same country even to this day is called in *Coptic* the land of *Cemi*; as we learn from the same *Samuel Bochart*.

This name therefore signifies something hidden, occult, mysterious, secret; and the Art which it expresses is called likewise, *Chemi*, *Chemia*, *Alchemia*, *Alkumia*, *χημᾶ*, *χημία*, *ἱμῶθ*, *ποιητική*, the *Spagarite* and *Hyssopic Art* separating the pure from the impure.

And by it, the Authors who first made use of the word meant, a universal knowledge of Nature.

The word therefore was used originally in a very pure sense, though it was afterwards perverted to a very different one; which misfortune likewise, by means of illiterate persons, befel the word *Magic*.

But as Metals now comprehend a large and very beautiful part of natural bodies; hence the same word came likewise to signify Metallurgy.

And this Art also was cultivated to great perfection by the Antidiluvians: for *Tubal-cain*, the true *Vulcan* of the Ancients, son of *Lamech* and *Zillah*, and the eighth person from *Adam*, understood how to prepare copper, and iron in such a manner as to work it into utensils, *Gen.* iv. 22.

But fossil copper as it is dug in the ore requires both exquisite art and labour to make it fit for use; no less than twelve fusions being necessary to render it sufficiently malleable; as both *Agricola* and *Erker* inform us.

And iron in like manner must be managed with a vast deal of skill and pains, before it can be applied to the same purposes; as we learn from the same faithful Authors, who were the top masters in this Art.

Hence therefore we see that the original of Chemical Metallurgy is exceeding ancient, as well as that of the name itself.

The country which is first celebrated for the cultivation of this Art, is that which was inhabited by the first people, as the History of *Tubal-cain* evinces (*Gen.* iv. 22): Especially, if you compare this with the Fables and Histories of the *Vulcan* of the Ancients, who was the same with *Tubal-cain*, (*Voss. Id.* g. I. 65.) And indeed the very name of the Arts seems by it original to confirm the same thing, as you have seen already.

The word used to express Metallurgy.

The difficulty of the metallurgic Art.

Chemical Metallurgy first cultivated in Asia.

From

Then in
Egypt.

From hence as its source, this, like other Arts, began to spread, and was next carried into *Egypt*; and there it was practised with a vast deal of application. For *Moses* who was skilled in all the learning of the *Egyptians* (*Acts* vii. 21.) knew how by the help of fire to reduce gold to a powder, so as to render it miscible with water, and by this means potable, (*Exod.* xxxii. 20;) and this is what is certainly one of the top performances of the Art, and what even the greatest Adepts of the present age are not masters of. *Vulcan*, the son of *Jupiter* and *Juno*, was the first who reigned in *Egypt*, and was deified after his death for the invention of fire (*Diod. Sic.* l.) or rather for the first application of fire to making utensils of metals, as the same Author says expressly (γ.) *They tell us, that Vulcan was the Inventor of all works in iron, brass, gold, silver, and other bodies that require the management of fire. He found out likewise all the uses of fire, which he discovered both to the workmen and every body else.*

But *Egypt* itself in the sacred language of the Priests is called *χημία*, (*Plut. Is. & Osir.* 364. C.) and *ἐμποχήμιος*, *Steph. Byz.* in the word *ἄιγυπτος*.

The same country likewise went by the name, *Ἡφαισία*, or the land of *Vulcan*, (*id. ib.*) The great *Scaliger* indeed asserts, that the Art *χημία*, was by the *Egyptians* called *ἱμῶθ*. And yet in the book entitled, *Minerva mundi*, taken out of *Stobæus*, it is said, *ποιητικῆς τ' Ἀσκληπίου τ' ἱμῶθης*, (*Conring. b. m. c. III.*) i. e. That *Æsculapius* the son *Imuth*, was the inventor of Chemistry; for *ποιητικῆς* is the same as *Chemia*, (*Reines. var. lect. lib. II. c. v.*)

Vulcan it is certain had Priests at *Memphis* (*Herod.* II. 3.) A very beautiful temple was erected to him there (*Herod.* II. 99.) with portico's (*id. ib.* 102.) and images (*id. ib.* 176. III. 37.) And his symbol there was a Vultur (*Vof. id. g. III. 573.*) viz. a bird of prey. But *Zeno* tells us that *Jupiter* too was called *Ἡφαισος*, on account of the extension of his influence to artificial fire (*Diog. Laert.* VII. 147.); which name plainly appears to be derived from *τὸ ἡφθαίει*, to be set on fire, or to burn. Agreeable to which opinion, *Horace*, who is remarkable for the elegance of his Epithets, expresses himself,

—dum gravis Cyclopum

Volcanus ardens urit officinas. *Carm.* I. 4. 7.

as *Plautus* indeed had done before him (*Amphitr.* I. 1. 1885.)

Quo ambulas-tu, qui vulcanum in cornu conclusum geris?

All these observations then seem to make it plain, that the part of Chemistry called Metallurgy, or the Art of Metals, was by the ancients cultivated chiefly in *Egypt*. Nor do I think there can be the least doubt about the antiquity of this very old Art, in this sense; or about the name itself.

The origin
of the word
as applied to
the Art of
making
gold.

A considerable time after, the same word first came to be used to express that Art, by which the purest gold might be procured from any sort of metal; either by a true transmutation, maturation, or some peculiar kind of separation, that was not commonly known.

Afterwards, the *Arabians*, who principally cultivated this Art, altering the found a little, called it *Alchemia* in the sense just now mentioned; and with a little more variation, *Alchimia*, *Alchemy*.

Very uncer-
tain.

Suidas, who lived in the tenth century, tells us (under the word *χημία*) that *Dioclesian*, who reigned the twenty last years of the third century, gave orders that all the books of this Art should be inquired after, and burnt, because the *Egyptians* were plotting against the *Roman Government*. *χημία*, (*Chemistry*)

or the Art of preparing gold or silver. The books concerning which, Dioclesian got together and burnt, because the Egyptians rebelled against him. He used them cruelly and without mercy; when he sought after their books that were written by their forefathers concerning the χρυσία of gold and silver, and burnt them, lest by the help of this Art they should grow rich, and so be tempted again to oppose the Roman government.

But under the word δέσας he carries the affair still a great deal higher, expressly and positively asserting, that the Golden Fleece, which Jason and the Argonauts brought away when they sailed thro' the Pontic Sea to Colchis, was nothing but a book written upon parchment teaching the method of making gold (διὰ χρυσίας) by the Chemical Art. This now, had he confirmed it by sufficient authority, would have advanced the antiquity of this Science to thirteen centuries before Christ, that is, before the time of the Argonauts. And yet upon this supposition we see the Art even at that time was known, practised, committed to writing, and was the motive to the Argonauts to undertake that fatiguing and dangerous expedition. If this was the case however, it must be confessed it is pretty extraordinary, that neither Moses, the Sacred Writers, Sanchoniatho, Orpheus, Homer, Hesiod, Pindar, Herodotus, Thucydides, Hippocrates, Aristotle, Theophrastus, Dioscorides, Galen, or Pliny should mention one word of it: Especially, as every body who is acquainted with their works must allow, that both the capacities of the Authors, and the design, subject, and times of their writing, must necessarily have led them to have taken notice of it.

Nor is this difficulty at all removed by that passage in Pliny (xxxiv. 25.) concerning flexible Glass; or by that of Dion Cassius (lvii. p. 617.) concerning the same project's being rejected by Tiberius; nor yet by the other of Pliny (xxxiii. 4.) where he tells us, that Cajus, by a very intense fire, procured from orpiment a small quantity of very choice gold: For supposing these things to be true, they in reality prove nothing more, than that they were at that time excellently skill'd, both in the docimastic Art, and that of Glass.

It must, however, be acknowledged, that Julius Maternus Firmicus, in the beginning of the fourth Century, writes of the Science of Alchemy, as a thing perfectly well known (3 Mathes. lv.) if this is the genuine text of the author.

'Tis ancient however, chiefly amongst the Greek divines.

And Æneas Gazæus, towards the close of the fifth Century, discoursing upon the same subject, as a common thing, tells us, in his Theophrastus, or treatise De Immortalitate Animæ, that those Persons who were thoroughly versed in this Art, take silver and tin, and perfectly destroying their original nature, transmute them into the most beautiful gold. Biblioth. Patr. vol. 2. pag. 373.

But Anastasius the Sinaïte, about fifty years after, as Vossius thinks (Id. G. l. i. pag. 25.) or rather towards the latter part of the seventh Century, as upon weighing the matter carefully, Fabricius is of opinion, (Biblioth. gr. v. pag. 313.) writes still more expressly; ἡ δὲ χρυσοχόος ἡμᾶς, ἢ λιθεργῆς, ἢ χημείας, χρυσοκολλήτων λίθων ἀπεργάζεσθαι, ἢ γεωφὴ βελομένη, ἢ παιδύσσει ταῦτα φησὶν.

And lastly, in the seventh Century, Georgius Syncellus, wrote professedly upon the same subject.

Soon after him, there sprung up a whole tribe of Alchemistical Writers, whose manuscripts at Rome, Venice, and Paris, by their Greek Idiom, make it plain what age they liv'd in; and by their style make it very probable, that

Christian Greeks the principal Alchemistical Writers.

Were they
the first
too?

A Catalogue
of these.

they were of religious orders. A Catalogue of these Works, which are not yet printed, we have in *Borrichius*, and others (*de Hermetis, Ægyptiorum, & Chemicorum Sapientia*, pag. 78. & seq.)

Σωέσις, whose treatise of the Philosophers Stone, is in the Library of the University of *Leyden*.

Συνέσις φιλόσοφος εἰς βιβλίον Δημοκρίτου. The whole treatise is in *Fabric. Bibl. Gr. L. v. cap. 22. p. 232. Gr. & Lat.*

Σώσιμος ὁ μέγας, ὁ θεῖος, ὁ Πανοπόλιτης, of πανάπολις a city of *Egypt*. xxiv. books ἱμεῖθ το Θεοσέβεια. The title is Σώσιμος τῆ παναπολίτις γνησία γραφή, περὶ τῆς ἱεράς, ἢ θείας τέχνης τῆ χρύσευ, ἢ ἀργυρεῖς ποιήσεως. and Ζώσιμος περὶ ὀργάνων, ἢ καμίνων.

Ἐλυμπιόδωρος ὁ Ἀλεξανδρινός.

Ἡλιόδωρος περὶ χρυσοποιήσεως.

Ἰωάννης Ἀρχιερεύς, τῆ ἐν αἰγίᾳ πόλει περὶ τῆς αἰγίας τέχνης.

Στέφανος ὁ φιλόσοφος ἀλεξανδρῶς οἰκονομικὸς περὶ τῆς ἱεράς, ἢ θείας τέχνης τῆ χρυσεῖ ποιήσεως. The Manuscript of this also is in the University Library at *Leyden*.

Ὡς. χημικὰ.

Σοφὰς ἐν περσίδι.

Ἐρμης handed about in the sixth Century, and commended by *Zosimus*.

Διόσκουρος ὁ ἱερεὺς μεγάλης Σεραπίδος ἐν Ἀλεξανδρίᾳ.

Ὁσάνης ἀπ' Αἰγύπτου πρὸς Πετᾶσιον περὶ τῆς ἱεράς, ἢ θείας τέχνης.

Μώσης προφήτης περὶ χημικῆς συντάξεως.

Μαρία Ἐβραῖα.

Πελάγιος φιλόσοφος περὶ τῆς θείας, ἢ ἱεράς τέχνης.

Πορφύριος.

Ἐπιβύχιος. ὁ Ἐπιβήχιος.

Κομάριος φιλόσοφος, ἢ ἀρχιερεὺς, διδάσκων τὴν Κλεοπάτραν τὴν θείαν ἢ ἱεράν τεχνίαν τῆ λίθης τῆς φιλοσοφίας.

Κλεοπάτρα ἡ γυνὴ Πτολεμαίᾳς τῆ βασιλέως. The same περὶ σταθμῶν ἢ μέτρων.

Κοσμάς ἱερομονάχης ἐρμηνεία τῆς χρυσοποιίας.

Ἀγαθοδαίμων εἰς τὴν χρησιμὸν Ὁρφέως σιναγωγὴν, ἢ ὑπόμνημα.

Πάππας φιλόσοφος ἔργον.

Ἡρακλεῖος ὁ βασιλεύς.

Σαλμανᾶ Ἀραβὸς μέθοδος.

Χρυσίανος περὶ τῆς θείας ὕδατος.

Θεόφραστος φιλόσοφος περὶ τῆς θείας τέχνης.

Ἀρχέλαος φιλόσοφος περὶ τῆς θείας τέχνης.

Κλαυδῖανος.

Σέργιος.

Ἀνεπίγραφος φιλόσοφος περὶ χημείας.

Μιχαὴλ ψέλλος περὶ χρυσοποιίας. He lived in the time of *Constantine Ducas*, in the year of our Lord 1060. *Borrich.* 79.

Ἰσὶς προφήτις τῷ ῥῶ ὧρῳ.

Βλεμμίδας ἔργον χημικόν.

Νικέφορος.

Δημοκρίτης βίβλος προφητικῆς λαλήσεως.

Δημόκριτος φυσικὰ ἢ μουσικὰ.

Ἱεροθεὸς φιλόσοφος περὶ λίθου ἡ φιλοσόφου.

Ἰσαακ Μόναχος, ὅπως δεῖ εὐρίσκειν μεθοδὸν ἀργύρου.

Concerning these Greek Alchemistical Writers, consult in particular, *Andreas Libavius* throughout all his Works; but especially against *Guibertus Conring. de Med. Herm. pag. 21, to 31. Borrich. Ort. Ch. 97.* and against *Conring.* from pag. 66, to 95. *Joann. Albert. Fabric. Biblioth. gr.* in various places. And the Catalogue of the University Library at *Leyden*.

Is it not surprising now, that the incomparable *George Agricola*, should have been acquainted with these Authors? For those elaborate Books of his, *De Re Metallica*, which the great *Erasmus* so highly extoll'd, he wrote, and perfectly finish'd, before the year 1550; and yet, in a very elegant Preface prefix'd to these Works, he recites in order, almost all the Writers we have just now mention'd. For your intire satisfaction on this head, I'll beg your patience, whilst I give you the passage in the very words of this noble Author. *Of Chemistry* (Χημειτικά) wrote *Osthanes, Hermes, Chanes, Zosimus of Alexandria* to his Sister *Theosebia*, *Olympiodorus of Alexandria* likewise, *Agathodæmon, Democritus*, not of *Abdera*, but another, *Oris Chrysorichites, Pebechius, Comerius, Joannes, Appuleius, Petasius, Pelagius, Africanus, Theophilus, Synesius, Stephanus* to *Heraclius Cæsar*, *Heliodorus* to *Theodosius*, *Geber, Calides, Rachaidibus, Verdianus, Rhodianus, Canides, Merlinus, Raymond Lully, Arnaud de Ville Nieuve, Augustinus Pantheus a Venetian*; three of the female sex, *Cleopatra, the Taphnuttian maid, Maria the Jewess*; these all wrote in prose; one only, *Joannes Aurelius Augurellus of Merrechia*, in verse.

All these Authors, however, made use of the Word Chemistry hitherto, to express the Art of converting the baser Metals into pure Gold; and don't seem so much as ever to have thought of any universal Medicine for all the diseases of the human body. See *Conring. de Med. Herm. 15, 16.*

The meaning of Alchemy.

But after the *Arabians* began to cultivate Chemistry in the sense hitherto described, viz. as it relates to Metallurgy, and the Art of making Gold, they seem by their metaphorical and hieroglyphical style, to have given occasion to the Materials made use of to perfect their Metals, going by the name of Medicines; the impure Metals being called sick Men; and Gold, a Man in perfect health and strength. Hence, in time it came to pass, that persons, who were unacquainted with this way of writing, imagin'd these expressions were to be understood in the literal sense; especially, when they saw the impurity of the baser Metal called a Leprosy, which of all distempers is particularly incurable.

The origin of medicinal Chemistry, from the misunderstanding the Expressions of the Chymists.

And this is supposed to have given rise to that report, which afterwards spread so far, and grew so common, that the impure Metals might be transmuted into pure Gold, by the very same chemical instrument, by which the bodies of sick persons might be restored to health.

And this instrument they call'd the *Philosophers Stone*, and the *Gift of Azoth*; and to the persons that were possess'd of it, they gave the name of *Adepts*.

And this prejudice a few simple Experiments afterwards rooted still deeper; for by these, they saw the healing vertues of Medicines might be extracted from them by the Chemical Art. Of this *Rhazes* had given some instances. *Avicenna* too, in the eleventh Century, had in his book, *De Viribus Cordis*, exhibited

The Authors in Alchemy after the Greeks.

hibited the same thing in the Julab of the *Arabians*, or the distill'd Water of *Roses*; and it was afterwards confirm'd likewise by *Mesue*.

Among these, the Authors of the greatest character are *Geber*, called the *Arab*; tho' *Leo Africanus* will have him to be a *Greek*: He was at first a Christian, but afterwards renounc'd his Religion. He wrote in *Arabic*, and liv'd in the seventh Century. The Library of *Golius* furnish'd us with his Works, which have been translated into *Latin* by various hands. See *Leo Afric. L. III. p. 136. Conr. h. m. 369. 372, 373.* He wrote chiefly

De Alchimia, vel Chimia; aut de investigatione perfectionis Metallorum.

De Summâ Perfectionis Metallorum.

De Claritate Alchimie.

De Lapide Philosophico.

De Testamento.

De Epitaphio.

De inveniendâ arte Auri & Argenti.

Morienus Romanus, a Hermit of *Jerusalem*: He wrote concerning this *Arcanum*, in a very elegant manner, and is reckoned among the purest Authors. His Works were translated out of *Arabic* into *Latin* the 11th of *February* 1182.

Albertus Magnus, a German, Bishop of *Ratisbon*, born at *Laving* in *Schwaben*, about the year 1200. He wrote

A Treatise *De Mineralibus.*

Lilium floris de spinis evulsum.

Speculum Alchemie de compositione Lapidis, &c. See *Borellus*.

Roger Bacon, a Briton, who was a Monk of *Westminster*, and resided at *Oxford*. He was famous for his knowledge in Alchemy, Chemistry, natural Magic, Mechanics, Metaphysics, Physics, and Mathematics; and was in vast reputation about the year 1226. Those of his Works that are come to our hands, are

Two Treatises, *De Chimia*, wrote in a plain style enough, without any design'd obscurities.

Speculum Alchemie, and another different from the printed one, the Manuscript of which is in the University Library at *Leyden*.

Thesaurum Chemicum.

De secretis artis, atque naturæ operibus, & de nullitate Magiæ. Specula Mathematica.

His Works *De Arte Chymie*, printed at *Francfort*, 1603. 12°. which contain a great many very beautiful observations in Mechanics, natural Magic, and various other Arts, the honour of which is unjustly given to modern Authors; and which were falsely imputed to Magic and Heresy. *Borrich. Ort. Ch. p. 122. and Borellus.*

George Ripley, a Briton, Canon of *Bridlington*, liv'd about the same time. He wrote *Duodecim portæ. Medulla Chymica. Alchemy*, the Manuscript of which is in the Library of the University of *Leyden*, in *English* verse. All his Works were printed at *Cassel*, in 8v°. 1649.

Hermesius, the Philosopher. He wrote a Treatise, *De Mercurio Philosophorum*. The Manuscript, in the Library of the University of *Leyden*.

Arnoldus, or *Arnaud de Ville Nieuve*, who liv'd in the thirteenth Century. His Writings are *Rosarium. Testamentum novum practicum. De Alchimia. Semita Semitarum.*

Rosa

Rosa Novella. A Letter to Pope Pius.

Novus Splendor, vel Lumen. Flos Florum. De Furno Philosophico. De Secretis Naturæ. De nova compositione Lapidis vitæ Philosophorum. De Principiis naturalibus to Pope Clement. *Opus in Arte Majore.* All these Treatises are in Manuscript, in the University Library at Leyden.

Raymond Lully, of Majorca, descended from a family of Barcelona. He was born in the year 1235, was a Scholar of *Arnaud de Ville Nieuve*, and died in Africa in 1315. He was one of the principal Writers of the universal Remedy for all diseases of the human Body, and of the *Lapis Aurificus*, in his Treatise *De Quintâ Essentiâ*. He wrote likewise, *De Secretis Naturæ, seu de Quintâ Essentiâ, & de Accurtatione Lapidis Philosophorum. Codicillum, seu vade mecum, de formatione Lapidum pretiosorum*; Manuscripts in the University Library at Leyden. *Claviculam de L. P. Testamentum Apertorium.* Some Letters to Edward, King of England. *Lux Mercuriorum. De Mercurio Speculum magnum. Testamentum Novissimum.* A Letter to *Robert King of England. *Aphorismi. Epistola Accurtationum. De investigatione occulti secreti. Exempla Accurtationis.* The Manuscripts of all these Treatises are in the Library of the University of Leyden. He is said to have wrote upon chemical Subjects, to the number of sixty Volumes.

* So in the original.

Joannes de Rupefissa a Franciscan Monk; he died in prison about the year 1375. He wrote various Treatises of Alchemy. See *Conr. H. M. Borellus*. *Paracelsus* said of him, that he asserted things that were both trifling and false.

Isaacus Hollandus, and *Joannes Isaacus Hollandus*, of Stolk, a little town in Holland. They wrote a good many things on Alchemistical Subjects, in which there are a great many very curious Experiments. *De Lapide Philosophorum. Scientia Chimiæ. De projectione infinitâ. De Mineralibus, & vera Metallorum Metamorphosi. De Vino. De Vegetabilibus*, and other things.

Basil Valentine. It is commonly reported, he was a Monk of the *Benedictine* Order at *Erffurt*; tho' it is confidently affirm'd, that there never was any such Monastery there; and indeed, both names seem to be a fictitious composition from the *Latin* and *Greek*: This however is certain, that he was a most expert Artist in every Branch of common Chemistry. That single Treatise of his, intitled, *Currus triumphalis Antimonii*, is a sufficient proof of this Assertion; for that alone contains an exact description of almost all the chemical Artifices that are now-a-days unfairly put upon the world for new discoveries: In the more abstruse parts of the Art too, he discover'd a profound knowledge. His very great fault was, that he extolled every Preparation of Antimony, without exception, for its medicinal virtues; than which, nothing can be more weak, fallacious, or mischievous. And this fatal error has infected all the Schools of the Chemists, from that time, quite down to the present age. It appears by his writings, that he was both a Monk and Physician; and seems by his learning, to have gain'd a very great reputation in the Courts of several Princes. He is supposed to have flourished in the Century before *Paracelsus*. He was the Inventor of the three chemical principles, which *Paracelsus* afterwards made great use of. He wrote a great many things in a pretty prolix manner, and some of them upon medicinal Subjects.

After these last five Authors had publish'd their Works, the opinion, as we just now took notice, every where got ground among the Chemists, that it was possible,

Chemists
and Alchemists become
Physicians.

possible, by one alchemistical Medicine, perfectly to root every distemper out of the human body, to restore absolute health, and prolong life to a great series of years, without being impair'd by any diseases.

Who being puffed up with some good effects of their Art, especially in the venereal Disease by the influence of Mercury,

Puffed up therefore with these expectations, and grown vain with the success they had had from some of their strong chemical Medicines, in a short time they were for engrossing the Art of Physic intirely to themselves.

At the same time too, the Art of Physic had for a good while, by the subtle sophistry, and jargon of the Schools, been become intirely *Galenical*, and given up to the doctrines of the *Arabians*: Hence bleeding, purging, and a few efficacious Medicines, being the sum of the practice, and these not being sufficient to encounter with the venereal Disease that then made havock among them, it was forc'd to give way to the more powerful Preparations of the chemical Art; for *Carpus*, by the assistance of his Mercury, easily out-did the Shoollmen, and thus afforded the Chemists fresh occasion of triumph.

promised new and incredible cures.

By this means, the condition of the old Physicians seem'd now to grow very uncomfortable; for after they had taken a vast deal of pains to search into nature, in order to discover the origin, and cure of diseases, these boasting Alchemists condemn'd all their labours in *Ætiologics*, *Diagnostics*, *Prognostics*, *Dietetics*, and *Therapeutics*, as trifling, and of no manner of service; whilst they, without any regard to diet, or the cause and nature of the disorder, could intirely remove all manner of distempers, by the simple application of one and the same Medicine.

But perform very little.

This extravagant error, however, by sweeping away great numbers at the first onset, made it appear, upon maturer consideration, that the bold pretensions of those practitioners were not only vain, but did likewise a great deal of mischief.

This we learn plainly from the life and writings of *Paracelsus* and *Van Helmont*, as may be fairly collected from the hints they have given us.

History of Paracelsus from himself.

Aureolus Philippus Paracelsus Theophrastus Bombast de Hobenheim, was the Son of *William Hobenheim*, a man of Letters, and Licentiate in Physic, tho' not much noted for his practice, who had a very fine Library, being himself a natural Son of a Master of the *Teutonic Order*.

He was born in the year 1493, in a village called *Einsidlen*, which signifies a Desert, two German miles distant from *Zurich* in *Switzerland*: And hence he came to be called the Hermit; which appellation *Erasmus* gave him, in the letters he wrote to him.

He is said to have had his testicles bit off by a hog when he was but three years old; and from that time he was looked upon as an Eunuch. This is certain he always behaved with the greatest aversion to the female sex; and yet a picture of him drawn from the life when he was grown up, represents him with a beard. Under the advantage of the faithful instructions he received from his father, he made great progress, both in medicine and surgery; but having whilst he was very young a vast fondness for Alchemy, his father committed him to the care of *Trithemius*, abbot of *Spanheim*, who was at that time in great reputation. Under him he got an insight into a good many *Arcana*, and then quitting him applied himself to *Sigismund Fuggerus*, who at vast expence and with a great many servants, was then strenuously prosecuting the chemical Art in *Germany*; which he had very much improved by abundance of new Discoveries.

And

And here it was, as he himself confesses, he learned both the Theory and Practice of the Spagarite Art.

Afterwards he tells us, he fought out, and studied under all the tutors, that bore the greatest reputation at that time of day, and were deepest skilled in the adept Philosophy; and they, he says, concealed nothing at all from him, but revealed to him all their *Arcana*.

However not being satisfied with this, in order to get a better knowledge of Physic, he visited all the Universities in *Germany, Italy, France, and Spain*; and travelled into *Prussia, Lithuania, Poland, Walachia, Transylvania, Croatia, Portugal, Sclavonia*, and in short into all the Kingdoms of *Europe*; and wherever he went he made it his business to inquire among Physicians, Barbers, old Women, Conjurers, Chemists, rich and poor, for the best and surest remedies, and was always very well pleased to be informed by any person whatsoever.

From the writings of *Basil Valentine*, he learned the doctrine of the three Elements, *Salt, Sulphur, and Mercury*, which he afterwards, concealing the Author's name, published as his own.

When he was twenty years of age, he took a view of a great many mines in *Germany*; and whilst he was on this expedition, wandering quite up into *Muscovy*, he was upon the borders taken prisoner by the *Tartars* and carried before the *Cham*, who sent him with the Prince his son to *Constantinople*: and here in the eight and twentieth year of his age, he is said to have become master of the *Philosophers Stone*.

In the character both of Surgeon and Physician he was often in camps, battles and sieges.

He had a high esteem for *Hippocrates*, and the ancient Physicians: as for the Doctors of the schools he made very little of them; and had a particular aversion to the *Arabians*.

Mercurials and Opiates he used plentifully and boldly, and with these he cured the Leprosy and Venereal Disease, the Itch, Ulcers, the lighter sorts of Dropsies, and acute pains; which Distempers were at that time of day beyond the reach of the Physicians; as they knew nothing of Mercury, and were afraid of Opium, from an idle notion of its being cold in the fourth degree.

By the cure of such distempers he grew bold and famous; but particularly by that which he performed upon *Frobenius* at *Basil*, which brought him acquainted with our great *Erasmus*. The Magistrates of *Basil* being on this account very well pleased with him, courted him with a very handsome salary to the Professorship of Physic and Philosophy in their University; which he accepted in the year 1527, and gave public Lectures for two hours every day, in the *Latin* tongue sometimes, but chiefly in the *German*.

The first public professor of Alchemy.

He took this opportunity to explain his own books, *de Compositionibus, Gradibus, and Tartaro*; in which, as *Van Helmont* observes, there is a great deal of trifling, and very little of any real service. And here he burnt the works of *Galen* and *Avicen* publicly from the chair; and declared to his pupils, that if God would not assist him, he should not scruple to consult even the Devil himself.

At this place he got a great many Scholars, with whom he lived in a very friendly intimate manner. Three of them at his own expence he furnished both

both with diet and apparel, and let them into some of his *Arcana*; but they deserted their master, wrote reproachful things against him, and injudiciously making use of the observations he had communicated to them, did their patients a vast deal of mischief. He maintained in his family likewise, Surgeons and Barbers, to whom too he communicated some of his secrets; but these likewise soon forsook him, and became his enemies. As his proper faithful scholars, he only speaks handsomely of Doctor *Peter*, Doctor *Andrew*, Doctor *Ursing*, Licentiat *Pangratius*, and Master *Raphael*. When he had been in his office two years, with three Pills of his Laudanum he cured *Liechtenfessius* a noble Canon of most terrible pains in his stomach, which had brought him so low that his Physicians had given him over. The Canon like other sick folks had from the beginning promised him an hundred Louis d'ors, if he restored him to health, but refused to pay it when he had got well; upon which *Paracelsus* in a merry manner told him, he had given him nothing else but three pills made of mouse dung; for which he was cited to appear in court by *Theophrastus*. The Judges proceeding according to their common law, and hence having regard not so much to his skill, as to the charge and trouble he had been at, decreed him but a trifling acknowledgment. This so provoked *Paracelsus*, that according to his custom he could not help accusing the Judges both of ignorance and injustice; and thus knowing himself guilty in some measure *læsæ majestatis*, he made what haste he could home, and by advice of his friends got privately out of the city, leaving his whole chemical *Apparatus* to *John Oporinus*. He did not however retire to any great distance, but for two years wandered up and down *Alface*, *Oporinus* all the while bearing him company, and waiting upon him: And during this time he was as happy in his practice, as he was dissolute in his life. This *Zwinger* informs us (*Theatr.* 1422), who at that time lived at *Basil*, and frequently heard the story from *Oporinus* himself.

He had then taken *Oporinus* for his *Amanuensis*, and servant. He was a famous man, and master both of the *Greek* and *Latin* tongue, but was led away by the vain expectation of being let into *Paracelsus's Arcana*. After rambling about with him however for two whole years, he found he could get nothing at all out of him, though he had left his own family purely on that account. Being quite tired therefore, and grown wiser at last, he left *Paracelsus*, and returned to *Basil*.

The immediate occasion, however, of his leaving him was the following accident. One evening as *Paracelsus* was merry making with some country fellows, he was sent for to a Peasant, that lay dangerously ill near *Colombaria* in *Alface*; but he being set in for drinking, and not caring to break company, put off going to see him that night. In the morning however he went, and when he came into the room, with a stern countenance asked whether the sick man had taken any thing, having some of his *Laudanum* ready to give him. The persons about him answered, that nothing had been given him but the Sacrament, as he was now just upon the point of expiring. Upon which *Paracelsus* flew into a passion, and told them, if he had sent for any other Physician, he had no occasion for him, and left the house immediately. This impious behaviour so shocked *Oporinus*, that he was afraid, he himself should some time or other suffer for the monstrous inhumanity of his master, and therefore resolved to take

take a final leave of *Paracelsus*, though he had a very particular value for him. *Zwinger, Theatr.* 2275.

Paracelsus had now lost what knowledge he had of the *Latin* tongue, and never after this settled in any place, but kept rambling about; never sober, neither changing his clothes, nor so much as going to bed; till at length after a few days illness, in which he held perfectly sensible to the last, he died through extreme weakness at a publick inn at *Saltzberg*, on the four and twentieth of *September* 1541, and in the seven and fortieth year of his age, though by the assistance of his *Elixir Proprietatis* alone, he had flatter'd himself with the years of *Metbusalem*.

Some of his works he publish'd himself, viz, The fourth part of his *Chirurgia Magna*, which he dedicated to *Hieronimus Bonerus* chief magistrate of the city of *Colmar*, the second day of *June* 1528. His Treatise *de Apostematibus*, which he presented to *Conrad Wiseram*, Consul at *Colmar* the 5th of *July* 1528, His books *de Gradibus*, *Compositionibus*, and *Tartaro*. *Chirurgia Magna*, which he addressed to *Ferdinand Cæsar*, from *Munchbrath*, *May* the seventh 1536. The second part of this, which he inscribed to the same person the eleventh of *August*, 1536. In these he quotes those works of his, that were already published; *De Archidoxis*, *De Sanationibus*, *De Sanitate Microcosmi*, & *Elementorum*. *De Generatione Naturalium*. *De Suppuratione*. *De Signis*. *De Characteribus*, & *Adeptis*. *De Pblebotomia*. *De Origine novorum Morborum*. *De Magia*.

This whole History of *Paracelsus* I have extracted from his own writings, from *Oporinus*, *Zwinger*, and *Helmont* in particular; nor has it cost me a little trouble. See *Van Helmont*, (p. 187. § 3. p. 324, 325, 698, 699.) As for the accounts given of him by other Authors, I was afraid to subjoin them, as a mixture of ill nature or prejudice in his favour seems too evidently to appear amongst them.

John Baptist Van Helmont, descended from a noble family at *Brussels*, was born in the year 1577, six and thirty years after the death of *Paracelsus*. In the year 1580, he lost his father, being the youngest of all the children, and then without the knowledge of his friends, and contrary to the inclination of his mother, he applied himself to the study of *Physic*, p. 833.

The life of
Van Hel-
mont from
his own
Writings.

In the year 1594, he had gone through a Course of *Philosophy*, being then but seventeen years of age, (p. 12. § 1.) He was a prodigious lover of books, and had carefully read over *Galen* twice, *Hippocrates* once, other *Greek*, and all the *Arabian* Physicians; and whatever he thought worthy of notice in them he had collected into a common place book. And hence, at this time, he gave publick Lectures in *Surgery* in the College of Physicians at *Louvain*, being appointed to that office, by the Professors, *Thomas Fyenus*, *Gerard Villers*, and *Stornius*, (p. 833.)

Who was
learned in
the liberal
Sciences,
Philosophy,
and Medi-
cine.

In the year 1599, he was made a Graduate at *Louvain*, in the two and twentieth year of his age, (p. 11. § 7.); and began to see the insufficiency of the schools, long before he was master of any good Medicines, (p. 423. § 2). In himself he experienced the unsuccessful method of cure of the schoolmen, being troubled with a slight Itch, which was happily removed by the assistance of *Sulphur*, (p. 256, 257). He then began to grow uneasy, that he being of a noble descent should be the first of the family, that had ever applied himself to the study of *Physic*; and for this reason he quitted his Profession, divided his effects among his relations, and went out of the country with a resolution never to return again, (p. 833). He threw away his library which cost him two hundred

Was made
Doctor of
Physic.

despaire d of
doing any
thing in
Physic.

hundred Pistoles, (p. 666. § 12), and wandered about for ten whole years, (p. 11. § 7). He then, by the assistance of an illiterate person, got a notion of *Purotechny*, and applied himself intirely to Chemistry. Within two years after he made himself master of certain Chemical Medicines, by which he was able to cure some Distempers, (p. 833).

In the year 1609, he married a wealthy virtuous wife, of a noble family; and with her he retired to *Vilvorden*, where he gave himself wholly up to the Chemical Art, (p. 41. § 7. p. 833, 838.)

At first setting out, by making some very dangerous Experiments, he frequently run a risque of his life, p. 719, 948.

He neither visited any patients, or followed his Profession with views to advantage, (p. 693. § 3.)

Practised
Phyfic.

And yet he tells us he relieved myriads of sick persons every year, (p. 835.)

He spent fifty whole years in distillations, (p. 241. § 1.) He was in great esteem with the Bishop and Elector of *Cologne*, who was vastly fond of Chemistry, and exceedingly well skilled in it. He was sent for by the Emperor *Rudolphus*; and invited to Court by two Emperors: but he would not accept their favours, (p. 833, 835.)

Could not
cure many
diseases.

He was not able to cure his two sons of the Plague, but lost them both, (p. 873); nor his eldest daughter of the Leprosy, though he spent two whole years about it, (p. 714. § 27); nor his wife, or maid, (p. 469); nor himself when somebody had given him poison, *Ibid.*

In the year 1624, he published a little treatise, *de Aquis Spadanis*, at *Liege*; and afterwards some other pieces.

Was ill
himself, and
endeavours
his cure by
the com-
mon me-
thods,

* In the sixty fifth year of his age, (p. 720, 721.) after he had passed his sixty third, on the third of the Kalends of *January*, 1640, he was seized with a Fever, accompanied with a slight *Rigor* that made his teeth chatter. He had a pricking pain about his *Sternum*, attended with a difficulty of respiration. What he spit up, was at first streaked with blood, and afterwards pure blood itself. He took the *Penis* of a Stag scraped, and his pain abated. Afterwards he drank one drachm of goat's blood. In four days time the bloody *Sputum* left him; but he was still at times troubled with a slight cough, with some discharge. His Fever still continued, and a pain in his *Spleen* succeeded, which he removed by drinking some wine made hot with Crabs Eyes: And in a short time all the symptoms disappeared, (p. 322. § 35.) In the year 1643, being exposed

But without
success,

to the fume of burning charcoal, he fell into a Syncope, (p. 242. § 19.) from the inconveniences of which he relieved himself by Sulphur of Vitriol, *ibid.*

thence sinks
under his
distemper.

On the eighteenth of *November*, 1644, he was attacked by an Asthma and two Paroxysms of a Pleurisy: Under this disorder he laboured seven weeks, and then died of a slight Fever from extreme weakness, on the thirtieth day of *December*, 1644. See his son's Preface, who after his father's decease published all his works.

Hence therefore it appears evident beyond dispute, that neither of these Authors, who were the most famous of the Chemists that practised Phyfic, were masters

* The account given us here of *Van Helmont's* age don't agree with the preceding one of his birth: for if he was born in 1577, he could not on the third of the kalends of *January*, 1640, be in his sixty fifth year. This, among other things, I mentioned to the learned Author, who is sensible of the disagreement, but says it stands so in the places quoted from *Van Helmont* himself.

of such a universal Medicine as they every where boast of; tho' where the *Viscera* of their Patients were found enough to bear the shock of their violent Remedies, it must be confess'd, they perform'd a great many noble cures.

And here we may likewise remark, that neither of these vain men, with all their pretensions to longevity, arrived in reality to that stage of life, that one can properly call old age.

Afterwards the celebrated Physicians, *Franciscus de le Boe Sylvius*, *Otto Tachenius*, and their followers, introduc'd the chemical Art into Medicine, and made this every where dependant upon it, both in Theory and Practice.

These things then being thus slightly gone through, it will be of service to a beginner, at his setting out, to examine carefully those Authors, who have digested the operations of Chemistry themselves into a regular system; and of these, the following are the most valuable.

Oswald Crollius. Basilica Chemica cum notis Jo. Hartmanni. Genev. 1658. 8vo.

Beguinus Tirocinium Chemicum, often reprinted. 8vo. and 12mo.

John Hartmann. Opera Medico-chymica. Francf. 1690. folo.

Glafer. Traité de la Chymie. Bruffels 1676. 12mo.

Le Febre. Traité de la Chymie. Leyden 1669. 12mo, 2 vol. Paris 1660. 2 vol. 8vo.

Le Mery. Cours de Chymie. Leyden 1716, 8vo.

Le Mort. Chymia Medico-Physica, &c. Leyden 1696, 4to.

Barchausen. Purosapia. Leyden 1698. 4to.

In the metallurgic part of the Art, the most celebrated are *Geber*, often printed in various sizes.

George Agricola. De Re Metallica, Lib. xii. &c. Basil, 1657.

Lazarus Erkern. Beschreibung aller furnemisten Mineralischen ertz, und bergwerks arten, &c. Francf. 1629. folo. The same in 4to. Francf. 1694, intitled, Aula subterranea, alias Probirbuch Lazari Erker.

John Rudolphus Glauber, throughout all his works publish'd separately, at different times, and in various sizes.

Joachim. Becher. Metallurgia Becheri. Francf. 1660. 8vo.

John Kunkel. Philosophia Chymica, experimentis confirmata. Amsterdam 12mo.

Olaus Borrichius. Docimastica metallica. Copenhagen 1680. 8vo.

In Alchemy the following are of greatest repute.

Geber, who *Bernardus* reckons amongst the *Sophists*.

Morienus.

Roger Bacon.

George Ripley.

Raymond Lully.

Bernardus, Count of *Trevisan*. He wrote in the year 1453.

Joannes Isaacus Hollandus, and who perhaps is the same

Isaacus Hollandus, who is more modern than *Arnaud de Ville Nieuve*, but antienter than *Paracelsus*. *Penotus* had such a value for him, that he imagin'd him, lying conceal'd in *Paracelsus's* time, to be *Elias* the Artist, the promis'd revealer of secrets. *Libav. Alchimia Pharmaceut. 122.*

Basil Valentine. Chymische Schrifften. Hamburg 1694. 8vo.

Artephius.

Theatrum Chemicum.

Chemistry
and Medi-
cine united,
and made
one Acade-
mical
Science.

A catalogue
of Authors
for the Prac-
tical part.

Alchemists

Turba Philosophorum.

Paracelsus. Opera omnia, in Latin, Genev. 1658. 2 vol. fol°.

————— *Higb-Dutch, Strasburg*, 1603. 2 vol. fol°.

————— *Higb-Dutch, Strasburg*, 1616. 2 vol. fol°.

Ireneus Philaletha.

Michael Sendivogius.

John Baptist Van Helmont. Opera omnia. Amsterdam, 1652. 4to.

For Chemistry apply'd to Medicine and Natural Philosophy.

The same *Van Helmont.*

Robert Boyle. In all his writings.

John Bohn. Dissert. Chymico-Physicæ, Leipf. 1698.

Dr. Cox and Dr. Slare. In several of the *Philosophical Transactions of the Royal Society.*

Messieurs Homberg, Geoffroy, and Le Mery, the younger. In the *Memoirs of the Royal Academy of Sciences.*

Georg. Ernest. Stahl. In his *Fundamenta Chymicæ. Norimb.* 1723. 4to.

But above all, the very ingenious *Frederic Hoffman*, in his *Observationes Physico-Chemicæ selectiores, libris tribus comprehensæ*, publish'd at *Hall*, 1722; a Gentleman, who has done a vast deal of service to the chemical Art, and enriched both Chemistry and Physic, with abundance of beautiful observations.

Chemical
Authors in
Medicine
and natural
Philosophy.

COURSE

COURSE of CHEMESTRY.

PART II.

Which delineates the Theory.

CHEMISTRY is an Art, that teaches us how to perform certain physical operations, by which bodies that are discernible by the senses, or that may be rendered so, and that are capable of being contained in vessels, may by suitable instruments be so changed, that particular determin'd effects may be thence produced, and the causes of those effects understood by the effects themselves, to the manifold improvement of various Arts.

Chemistry defined.

And certainly, it very justly deserves the name of an Art ; inasmuch as it directs us to the performance of such actions, as the understanding certainly knows will produce such and such effects.

The objects, in observing or changing of which this Art is conversant, are all sensible bodies ; and that whether they are so in their own nature, or such, as tho' they were before imperceptible, yet by the help of this Art, either in themselves, or by their effects, may be brought within the reach of our senses ; especially, if they are naturally capable of being contain'd in vessels ; or by the power of this Art, may be so managed, as to be confin'd therein.

The objects of the Art.

Now, from an accurate consideration of these bodies, it appears, that they may commodiously enough be distributed into three Classes ; and these have obtain'd the names of Kingdoms.

Dispos'd into three Classes.

The first Class comprehends Fossils, or, as they are vulgarly called, Minerals ; which are defined natural bodies, generated in the bowels, or on the surface of the earth, whose texture is so simple, that the most accurate observers, assisted by the nicest microscopes, have never been able to discover any difference in them of vessels and contained fluids, nor any part of them, but what is perfectly uniform, and similar to the whole ; tho' at the same time we certainly know, that most of them are compounded of parts, both solid and fluid : These the Chemists call the Mineral Kingdom.

The first including Fossils. Character of Fossils.

Of METALS.

And among these, the first place in order is given to Metals ; whose character is, that they are the most ponderous Fossils, melting in the fire, uniting again in the cold, and then being ductile under the hammer.

The first place given to Metals. Marks of Metals.

Now of these, if we consider them simply, there have never yet been discovered more than six, viz. Gold, Silver, Copper, Tin, Iron, and Lead.

The ancient Philosophers indeed, added Mercury; but as that has neither Hardness, Ductility, or Fixity, it must certainly be of quite a different nature: The place however where it is found, its weight, simplicity, and easy union with Metals, naturally led them to think in this manner; and indeed, 'tis a very ancient, and has been a very prevailing opinion, that Mercury constitutes the principal part of all Metals.

The ancient
characters
of Metals.

The most ancient among the *Persians*, which is pretty remarkable, in their religious affairs, constantly made use of the same Names, for the seven Metals they saw produced in the Earth, which they had given to the Planets in the Heavens.

The Astronomers too, and Astrologers, have distinguished the heavenly Planets by the very same Characters ☉, ☿, ♀, ♁, ♂, ♃, ♄, as the Chemists do their Metals.

The mean-
ing of these
characters.

Which of them made use of these Marks first, it is not easy to determine; but this is certain, that the Chemists, by their hieroglyphical manner of writing, have aptly express'd the Bodies they design'd to represent, as upon examination will easily appear.

✱ Denotes every thing that is sharp and corrosive, Vinegar, Fire; and hence it has those sharp points which you see all round it.

☉ — whatever is perfect, immutable, and most simple: Such is Gold, in which there is nothing corrosive, or heterogeneous.

☿ — half-gold; whose inward part turn'd outwards makes pure gold, without any thing foreign, or corrosive. This the Alchemists have observ'd in Silver.

♀ — the inmost part pure Gold; but that at top there appears the colour of Silver, whilst underneath there is something sharp and corrosive; both which being remov'd, there will remain pure Gold, but *Aurum vivum*. This the Adepts assert to hold good in Mercury.

♁ — the greatest part to be gold; but that there is still a considerable quantity of a crude, sharp, corrosive matter join'd with it, which being separated from it, the remainder will have the properties of Gold. This also the Adepts declare the truth of.

♂ — that this too is intimately Gold; but that it has with it a great deal of the sharp, and corrosive; tho' with but half the degree of Acrimony as the former, as you see it has but half the sign that expresses that quality. And what the Alchemists assert, the Physicians observe to be true: Indeed, it is almost the universal opinion of the Adepts, that the *Aurum vivum*, or *Philosophorum*, does lye conceal'd in Iron; and that here therefore we must seek for metalline Medicines, and not in Gold itself.

♃ — that Tin is half Silver, the other half a crude corrosive Acrimony: And this every one who is used to docimastic trials experiences the truth of; for the Cupel shews, that it has pretty near the same fixedness in the fire with Silver; and that it contains abundance of crude Sulphur, well known to the Alchemists.

♄ — that it is nearly all corrosive, with some resemblance of Silver; which to the skilful is sufficient.

♄ — Chaos,

⊗ — Chaos, τὸ πᾶν. The world. The one in which are all things. Gold, and a large quantity of an arsenical corrosive.

The individual proper character of Metals, is their extraordinary weight, which far exceeds that of all other bodies: And this, as it is of all properties the most difficult for Art to produce, affords us a certain mark of Metals.

A catalogue of them, as they have been examined in the purest water, I have here inserted from the *Philosophical Transactions* N°. 169, p. 926. N°. 199, p. 694.

⊙	19636.	⊗	7852.
⊙	14019.	⊗	7321.
⊙	11345.	Granate	3978.
⊙	10535, 11087.	Glass	2805.
⊙	8843.	Pump Water	1000.

Weight, the true mark that distinguishes Metals from one another. And from other very heavy bodies. The rules drawn from the weight alone certain, and of great use.

If we want therefore to be satisfied, whether bodies that we are not acquainted with, have any quantity of Metal in them, the consideration of their weight furnishes us with the best method of trial.

Nay, and by this means it often appears too, of what sort it is.

How great therefore must be the difficulty of increasing the weights of bodies to such a degree, as to condense other Metals into Gold, or to convert other bodies into Metals?

Hence again we see farther, what substance comes nearest to Gold, in respect of its weight, and of consequence, is most likely to be transmuted into it.

And lastly, that the demonstration from weight is infallibly certain.

⊙ 1. Of all bodies is the heaviest.

2. The most simple, or homogeneous.

3. The most fix'd, both in Air and Fire: Nay, it is so to such a degree, that an ounce of Gold has been kept in fusion for two months together, in the Eye of a Glass-house furnace, without losing one Grain of its weight. Hence it appears to be incorruptible.

4. It is the only body that is capable of resisting the power, both of Antimony and Lead; nor when it is melted with them, does it run into *Scoria* with 'em, like other Metals, but sinks to the bottom. Hence it is the most durable of all bodies we are hitherto acquainted with; nay, perhaps immutable, by any physical power: And for this reason, the wisest among the Alchemists, have unanimously agreed, that it is easier to produce Gold by Art, than it is to destroy it.

5. Of all bodies 'tis the most ductile. The workmen can hammer out a grain of Gold, between skins made of Ox's guts, into a leaf, that shall contain $36\frac{1}{2}$ square inches, and 24 square lines. Forty-eight ounces of Silver shap'd into a cylindrical form, may be gilt with one ounce of Gold; from this, Wire may be drawn so fine, that 2 ells of it shall weigh no more than one grain; and consequently, in the surface of these 2 ells, there must be extended $\frac{1}{48}$ of a grain of Gold; and yet upon examination with a Microscope, the Gold is found to be spread so thick, that there is not, in any part of the surface, the least appearance of Silver under it. Hence therefore it follows, that $\frac{1}{100000}$ of a grain of Gold may be discern'd by the naked Eye; and that the thickness of this visible Foliage, is no more than $\frac{1}{334500}$ of an inch. Halley. *Philosop. Transact.* N°. 194. p. 549.

The true marks of Gold.

And

And in the *Mem. de l' Acad. Roy. des Scien.* 'tis demonstrated, that the gilding on the smallest Silver wire, is but $\frac{1}{1050000}$ of a line thick. A single drop of a Solution of Gold in *Aq. Reg.* will give a metalline taste to a pint of rectify'd Spirit of Wine; and will change some quarts of Water, that have two grains of Tin dissolv'd in it, to a dark purple colour. *Hoffman.* A workman at *Ausburg*, by a particular Art of his own, could draw one grain of Gold into a wire of 500 feet long. *Cassius de Auro*, pag. 77.

6. It is soft, scarcely elastic, or sonorous.
7. When it is once red hot, it presently melts; but in *Madagascar* there is a very soft sort, which runs like Lead with a gentle Fire. *Flacourt. Hist. Inf. Madagasc. Borrich. Ort. Ch.* 49.
8. Nothing will dissolve it, except Sea-Salt, or some *Menstruum* prepared from it, all other Salts having no effect upon it; and hence it comes to pass that it never rusts, as there is no such thing as *Aq. Regia*, or Spirit of Sea-Salt in the Air.
9. It very readily unites with Mercury, if it is pure; but not so easily with crude Mercury, as people generally imagine; no, not even by the assistance of Fire.
10. If it is dissolv'd in *Aqua Regia*, and precipitated with Salt of Tartar, it will, like Gun-powder, acquire an explosive Power. Gold is never corrupted by rust; or in the longest time, loses any thing by exhalation: Nature gives it perfectly pure in grains and glebes, of which there have been some found, that have weighed two pounds; and this Gold is called *Obyrium*; but it often requires the management of the Fire, as there is scarcely any Glebe that contains pure Gold, without a Mixture of some other Metals; unless, when it is most intimately united; and even then, it has in it something of Silver: But Silver and Copper excepted, 'tis rarely observ'd to be mixed with any other Metal: Almost all the world over it is distributed, more or less, and is found sometimes in a white Glebe, with black spots, which is accounted the best; at others in black, red, or yellows. In the Glebes, as they are dug from the Mines, there is observ'd a white, blue, red, and green Vitriol; and what goes by the name of Antimony of Gold.

It is separated from the Ore, 1. By torrifying it in a reverberating Furnace; by which means the volatile parts are carried off. 2. By boiling it in Water, that the saline and pinguious parts may swim at top, and so be easily taken away. 3. By rubbing it with Mercury, if the Mass is not pinguious. 4. By rubbing it with Mercury, and *Calx* of Vitriol, if the Glebe is fattish, and then boiling it in Water. 5. By *Aqua Regia*. 6. By certain Salts, which serve to fix the volatile Oil, or Salt; for these would otherwise carry off with them a considerable part of the Gold. 7. By washing it with Water; which is practised chiefly with Gold Dust.

See upon this head, *Lazarus Erker*, Lord *Verulam*, and the *Philosophical Transactions*.

Proper
marks of
Mercury.

- § 1. Of all bodies comes the nearest in weight to Gold; and the more so, the more it is purified.

2. It is the most simple of all bodies*, Gold itself not excepted, if it be perfectly pure.
3. In the Fire, it intirely evaporates in form of Smoke, with a degree of Heat, little greater than that of boiling Water.
4. It is not at all ductile under the Hammer, but will, by a gentle stroke, be divided into very small Particles; and the more so, the purer it is: No degree of cold has ever been observed to condense it into a solid Mass. Is it therefore fluid Gold?
5. Of all Metals, it unites the easiest with Gold, then with Lead, Silver, and Tin; with more difficulty still with Copper; and scarcely at all with Iron. In the union therefore of Mercury with Metals, as Mercury is the *Basis* of them all, is it not the Mercury, that by an affinity of nature, unites with itself? Hence, does it not unite so much the easier with any Metal, as that Metal contains more of Mercury, and less of any other Matter? This certainly seems very probable.
6. Both *Aqua Fortis*, and *Aqua Regia*, will dissolve it.

Hence then we may conclude, how difficult a piece of work it must be, to convert Mercury into Gold, as we must first give it weight, fixity, and ductility: In its nature, however, it approaches the nearest to Gold.

The greatest quantity of it now a-days, is found in *Friuli* in *Italy*, where it is produc'd, 1. In a *Matrix*, hard like Stone, and of the colour of *Crocus Metallorum*. 2. In a soft Earth, which yields fluid Mercury. 3. In Stones of a globular figure. 4. In *Cinnabar*.

It is separated from its *Matrix* by distillation; or by sifting it, and washing it with Water. That which in the Mines is found spontaneously fluid, without the assistance of Fire, is called *Virgin Mercury*.

- h. 1. Comes next in weight to Mercury.
2. It is found by every sort of trial to be exceeding simple.
3. It fumes in the Fire, and if kept melted a good while runs through most Vessels; nor is it of a fixed nature.
4. It is the softest and least elastic of all Metal; not sonorous; easily ductile.
5. Next to Tin it melts with the least degree of Fire long before it is red hot, throws out a Calx, and quickly turns into Glass, which put again into fusion no vessel in the Fire is able to contain. Any light things thrown into it, it casts up to the Surface. It vitrifies with impure Metals; and carries them with it out of the concave Surface of the Test, leaving Gold and Silver only, pure from all the others. The rest it either dissipates in Fumes, or draws with it through the pores of the Test. After fusion, it presently hardens again into a solid Mass, but not so quick as Tin.
6. It dissolves in *Aq. Fortis*, but not in *Aq. Regia*, and yields a sweet salt.

There is abundance of it in a great many Mines in *Europe*; the consumption of it is very great; and though it is cheap, it is a Metal vastly useful, as well

Marks of
Lead.

* This seems to contradict what was asserted before of Gold; and indeed it does so, except you understand it in an Alchemistical sense, which was what our Author design'd. For these Gentlemen tell us, that Mercury is the *Basis* of all Metals; and that Gold itself is compounded of Mercury and a fixing Sulphur, which consequently therefore must be less simple than pure Mercury, which they unanimously agree to be perfectly homogeneous.

as of a wonderful nature. In the Fables of the Mythologists, it is called the Origin and Father of all other Metals, and at the same time their Destroyer.

7. Its Ore is heavy, shining, and of a lead colour, and is half Lead; 'tis sometimes too, white, red, or yellow; but these are not so rich. It has frequently somewhat of Silver in it, which is apt to impose upon the Assayers, if they are not aware of it.

Marks of
Silver.

1. Is the next heavy Metal to Lead.
2. This also is simple, nor shews the least dissimilarity in its parts by any common trials.
3. It is so fixed in the Fire, that it hardly diminishes, if it is perfectly pure. After keeping it fused in the Eye of a Glass-house Furnace for the space of two months it is said to have lost scarce $\frac{1}{12}$ of its weight; and it is a question whether that Silver was absolutely pure.
4. It is malleable, and may be drawn into exceeding fine Wire.
5. As soon as ever it is grown red hot, it melts.
6. It is dissolvable in *Aq. Fortis* alone.
7. It may be purified with Lead, being able to resist it.
8. With Antimony it runs into *Scoria*, and becomes volatile.

It is found in a great many places, in various, and very different beds, and has commonly a small quantity of Gold interspersed with it. There is often in the Ore a corrosive, bituminous Sulphur, which renders the Silver volatile, and carries it off; or changes it into glassy *Scoria*, much to the disadvantage of the Owners. It yields neither to Salt, nor Lead, and therefore they manage it with Mercury; and this they do by mixing it with the Ore after it has been torrifed and reduced to powder, and then in rubbing them together for a considerable time, by which means the Silver unites with the Mercury, and this they afterwards draw off by distillation. *Phil. Trans.* 589, 590, 591.

Marks of
Copper.

1. Is the next ponderous Metal to Silver.
2. It is simple likewise, though less so than the preceding.
3. In the Fire it is pretty fixed, but fumes, and discovers some volatile parts.
4. It is ductile under the hammer, and may be drawn out into very small Wire; it is very elastic too, and of a sharp sound.
5. It grows red hot before it melts, and requires the greatest degree of Fire to fuse it, next to Iron. When it is in fusion it wonderfully resists Water, and is agitated by it in a most violent manner, and hence if any Water happens to come to this Metal whilst it is melted, the event is exceedingly dangerous.
6. It is easily dissolved by any salt, and then becomes greenish, or blueish; but soon getting rid of its dissolvent, it grows of a dirty disagreeable colour, losing all its former beauty: Hence both in Air and Water it contracts a greenish mould, which is nothing but a collection of small Crystals.
7. With Lead and Antimony it readily runs into *Scoria*, or is changed into Glass; and then leaves the Test, either going off in fumes, or running through the pores of it.

Mines every where abound with it, when it adheres so firmly to its stony Ore, that it commonly passes fourteen Fires before it is pure. It has frequently Silver mixt with it, especially, in the black or light blue Ore; the yellow, green, and brown contain less: In its veins are very often found, green, blue, reddish

reddish and white Vitriols ; and very fine green and blue stones : So that there is no metallic fossil matter enriched with a greater variety of beautiful colours.

§ 1. It too distinguishes itself by its weight.

Properties of
Iron.

2. It is less simple than the preceding, having manifest marks of a crude Sulphur, and a truly combustible matter, which may sometimes be raised into flame.
3. It is fixed indeed in the Fire, though not so much but that it fumes, throws out sparks like combustible Substances, and constantly loses of its weight.
4. It is ductile under the hammer, and may be drawn out into Wire, if you don't attempt it too fine ; for then it will split, or discover its brittleness : It is hard, and sonorous.
5. It grows red long before it melts, requiring the strongest Fire, and being melted with most difficulty of all Metals. When it is perfectly red hot, it will bear the contact of cold Water.
6. All Salts readily dissolve it, with which it changes of a red colour ; but it easily gets rid of its dissolvent, and then wastes into rusty *Scoriæ* : Hence it is scarce possible to preserve it from rusting.
7. Of all Metals, it is the most easily destroyed : with Lead, and Antimony it presently turns into *Scoriæ*.
8. It both attracts, and is attracted by the Loadstone.
9. It is endued with a medicinal virtue very beneficial to the Human Body, in which it may be nearly dissolved, and to which it seems to approach nearer in nature than any other Metal.

It is observed to be generated in all parts of the earth, dispersed through fat clayey earths, which being put into the Fire discover this Metal by their red colour. In the stony Ore it distinguishes itself by a rusty colour, or if the vein is extraordinary fine by a pale blue one ; nay, and often by its magnetic virtue. It is evidently contained in the native green Vitriol. It requires, however, the greatest degree of Fire to procure it pure from the Ore, as well as the assistance of certain proper materials, and a previous torrefaction in the Fire.

¶ 1. Of all Metals is the lightest.

Character of
Tin.

2. It is much less simple than the former, emitting with a gentle Fire sulphureous fumes, which are easily separated from the metalline part, and are almost combustible.
3. Hence, it is much less durable in the Fire.
4. It is soft, easily bent, and ductile under the hammer, and may be drawn into Wire, but with much more difficulty than the former : It is not considerably sonorous, or elastic.
5. It melts much sooner than the other Metals, long before it is red hot, and in a degree of heat not much greater than that of boiling water ; but grows hard again immediately in the cold.
6. Whilst it is crude, and retains its natural Sulphur it is dissoluble only in *Aq. Regia* ; but if by Calcination it is purified from its Sulphur, even Vinegar will dissolve it ; and a little matter of the Solvent is sufficient.
7. It resists Lead and Antimony so strongly in the Cupel, that it cannot be forced out of it without great difficulty ; and not at all indeed, without the assistance of Copper.

E

8. In

8. In many of its properties it comes near to Silver.

The Ore which produces it, is exceeding ponderous, though the Metal itself is but light. The Glebe it is found in is of a brown colour inclining to yellow, or, which is the richest, of a black one, smooth and shining, and sometimes not unlike the Iron Stone: It is contained likewise in a rocky substance very heavy and porous.

After the Ore has been burnt, pounded, and washed, it is melted, and separated from its Dross. The best sort of it is found in *Great Britain*, which yields vast quantities; and hence *Bochart* was led to conjecture that the word *Bretania* was derived from the *Syriac Barat Anac*, which signifies a field of Tin.

This History of Metals, which is undeniably true, furnishes us with the following observations.

The true principles of the transmutation of Metals.

1. That Metals are absolutely different from all other bodies hitherto known, whether natural, or artificial; as we find that the lightest Metal weighs more than twice as much, as the heaviest body of any other kind.
2. That they must therefore be vastly in the wrong, who pretend to convert any other body into Metal; for as the weights of bodies shew us exactly the quantity of matter they contain, the condensing them must be infinitely difficult, and scarcely to be effected without a creating power.
3. That the most certain rule of judging, how nearly pure Metals are alike in their intimate substance, is to be drawn from the nearness of their weights.
4. That there is no Metal therefore that comes so near to Gold, as Mercury, if you consider only their matter; for as to the other principle which gives to each its particular form, it must be quite of a different nature, and therefore does not enter into our present inquiry.
5. That the other properties of Metals, such as, fixity, colour, malleability, and simplicity, may possibly be more easily changed and produced.
6. That Gold consists of a most pure, simple matter, very like Mercury, fastly held together by another exceeding subtil, pure, and simple principle, which being intimately dispersed through the whole, firmly unites the Particles of the former both with itself, and with one another: These two principles are supposed to be Mercury and Sulphur.
7. That the other Metals are compounded of the same principles, but that they have likewise a mixture of another lighter substance in them, which in every particular Metal is different, and is called Earth; and hence they appear to be composed of three sorts of matter, to which in some of them, as a fourth, you may add a crude Sulphur.
8. That they may be resolved therefore into these their compounding Elements, which in different Metals, both in nature, and number, will be different.
9. That this may be effected, by Mercury, a resuscitating Salt, or Fire; by various methods, in various Metals.
10. That there is very little reason therefore for asserting that Metals are easily transmutable into one another, except you confine it to their mercurial part alone, their original Texture being first perfectly destroyed; and that hence no more Gold can possibly be procured from any other Metal, than in proportion to the quantity of Mercury which that metal contains.

11. That

11. That it does not in reality appear, that there ever has been any Metal produced by Art, different from the six which have been mentioned; notwithstanding what *Van Helmont* boldly asserts of Mercury fixed by his *Alcabeft*.
12. A person therefore acquainted with what has been said of Metals will not easily be imposed upon by empty promises, and specious appearances; since none of these deceitful Pretenders could ever truly counterfeit the weight of Gold, or produce a body that would be so fixed in the Fire as Gold or Silver: by these two properties then we shall be always secure against their cheats, or plausible reasonings, and be able to discover their spurious, artificial Metals; which brought to the anvil too generally want malleability.
13. That the six Metals, if they are melted in pure vessels, have all the very same appearance, and perfectly resemble Mercury, in colour, solidity, contraction of themselves into a spherical figure, attraction of their Particles, degree of fluidity, and mobility. Hence perhaps Mercury may be a Metal that requires the very least degree of heat to put it in fusion. Tin a Metal that won't run without a greater degree of fire; so that supposing the Air to have as much heat in it as is necessary to put Tin in fusion, then Tin would be Mercury, but would fume, and cast up a scum. Again, Lead would become Mercury, in a degree of heat still a little greater, but would throw out a scum too, and run through the vessels it was put into. A much stronger Fire still is necessary to reduce Gold and Silver to a state of fluidity, which would then be Mercury, and immutable. Copper requires yet a greater degree of heat to fuse it, and reduce it to Mercury, and then too it would be subject to change. And lastly, Iron which of all Metals runs in the Fire with the greatest difficulty, would then be fluid Mercury also, but as the former, would be likewise mutable.

Of S A L T S.

Salts, sometimes called concreted Juices, claim the next place in order to Metals; inasmuch as they are exceeding simple and enter into the composition of Semi-metals, and other Fossils. Fossil Salts.

By Salt, we mean a Fossil, which dissolves both in Fire and Water, and is of so simple a nature, that every single particle of it is similar to the whole, and impresses a taste upon the tongue. Its different sorts.

The natural Salts are, Sea Salt, *Sal Gem*, or fossil Salt, Fountain Salt, Nitre, Borax, native *Sal-Ammoniac*, Alum, and a Vague-acid of the pits. Fossil Salt, *Sal-Gem-me*.

Fossil Salt, the purer part of which is called *Sal Gem*, is found in different parts of the world, and is dug out of its pits perfectly pure, in vast quantities, and to prodigious depths.

Fountain Salt, is procured from running water, in which it is found dissolved, and when it is depurated, and inspissated, is exceedingly like Sea Salt. Fountain Salt.

Sea Salt, is dispersed throughout the Sea, and by simple evaporation, and purification is reduced into Chrystals. Sea Salt.

These three sorts of Salt, though they are different as to their manner of production, yet are found to be of the same nature; the same quantity of Water dissolves

solves them all, viz. $3 \frac{1}{4}$ times their own weight; in our air they all spontaneously melt away; the Chrystals they form are nearly alike, being cubical, parallelopipedal, or pyramidal, tho' one chrystallizes quicker, another slower; if they are put into *Aq. Fortis* they produce a *Menstruum* that will dissolve Gold; if they are urged by Fire they all yield an acid spirit, of the same nature; when they are dissolved in moist air, they leave a great deal of earth, and a fat, sharp, astringent liquor; they crackle in the Fire, which, if it is strong, will melt them; and then, if they are very pure, they will remain fixed in it a great while without undergoing any alteration; they yield no spirit, and but very little water; no Alkali can be procured from them; nor are they susceptible of putrefaction.

Nitre.

Modern Nitre, or Salt-petre, whose chrystals are octogonal prisms, is a semi-fossil extracted from an acrid, nitrous earth: it is put into fusion by a moderate Fire; scarce any water exhales from it, and 'tis pretty fixed: when it is melted it deflagrates with any inflammable substance: it dissolves in $6 \frac{1}{3}$ times its weight of water.

Nitrous earth, or stone, owes its virtues to the excrements of animals, or their putrified carcases (those especially, whose food has nothing of Sea Salt in it, as birds in particular,) when the ashes of burnt vegetables, and quick lime happen to be mixt with them: and the nitrous matter being thus produced, is diluted with a great deal of water, filtered through sand, and then formed into chrystals with octogonal bases.

Nitre is generated from a fat alkaline earth, and air. *Hofm. de Est. Aq. Min.* T. II. p. 42.

Borax.

The third Salt, is Borax, or *Chrysocola*, which is a fossil of various figures, requiring more than 20 times its weight of water, with a great degree of heat, to dissolve it; its taste is bitterish, but with a sort of sweetness at its going off; it melts very easily in the Fire, and then runs off in a rising froth, by which means a great deal of water is separated from it, whilst the remainder subsides into a beautiful kind of glass: It very much forwards the fusion of bodies that are mixt with it; and hence is of great service in soldering of Metals, Gold in particular.

Fossil Sal
Ammoniac.

Next in order comes *Sal Ammoniac*, or *Sal Arenarius*, which is produced in the most scorching parts of *Lybia*. The *Sal Cyrenicus* of the ancients, which was in such great abundance about the temple of *Jupiter Ammon*, appears by *Pliny's* description of the best sort of it, to have been exceedingly like the *Sal Ammoniac* of the moderns. The burning mountains too in different parts of the world cast out this sort of Salt; of which that from *Vesuvius* even to this time is esteemed the best.

And the
modern fac-
titious.An acid fos-
sil Salt.

It ought, therefore, to be referred to the class of fossils; though that indeed which is brought to us now a-days from *Egypt*, is supposed to be an animal production. In reality, does it not every where owe its origin to foot?

The fifth of the simple fossil Salts, is an acid, vague, volatile, liquid one, dispersed perhaps every where throughout the Mines: This being united with a fossil Oil, as the *Petroleum*, *Oleum terræ*, and the like, may possibly produce the different sorts of native fossil pellucid Sulphurs, called quick Sulphurs; as well as those which are found united with the Semi-metals, Cinnabar, Antimony, and other Fossils; and that both the fluid and solid: with Metals it produces

produces the various sorts of Vitriol; with earths abounding with Lime the different Alums; and lastly from the *pyrites*, which is the *matrix* of Vitriol, calcined in a quick Fire, it gives us the common Sulphur.

Is not this exceeding like that acid, which fumes from the blue flame of burning Sulphur, and is so suffocating and destructive to all animals? certainly its analysis, and resolution would lead one to think so.

And for these reasons perhaps it may not improperly be looked upon as a male Salt, which seems to impregnate the female Salts, and earths.

The sixth, and last is Alum, which is a true Fossil, procured either from a *Alum* stone that lies deep in the earth, which is hard, capable of being cleft, abounds with Bitumen and Sulphur, and is easily inflammable; or from a bituminous combustible earth, which in burning sends forth a sulphureous stench, that is very pernicious: This matter exposed to the air for the space of a month, moulders into a powder, from which Alum may be then produced, though the earth was unfit for it before.

If the stony substance is first exposed to the air, and then burnt, it will flame, and by its smell make it evidently appear it contains Sulphur.

The matter therefore being thus prepared, by the air only, if from the earth; but both by air and fire, if from the stone; it is dissolved in water, and then by the addition of a fixt, or volatile Alkali is precipitated with an effervescence; by which action the predominant acid being united with the Alkali produces a new Salt; which therefore owes its being to the air, the Alkali, and the Fossil.

The precipitated matter being then separated from its *Lixivium*, and dissolved in boiling water, is inspissated in a leaden vessel and put into a tub, where after some time it shoots into white, or reddish octagonal chrystals; of a sweet roughish taste; not easily dissoluble in the air; and that require fourteen times their weight of water to dissolve them.

The acid of this Salt when it is forced out by the Fire, is like the acid vapour collected from burning Sulphur, in almost every property.

After the acid is drawn off, the *faeces* that are left behind, yield a large quantity of a light, subtil earth, which very much resembles bole.

If it is burnt with triple its weight of charcoal, it gives the Phosphorus of *Homburg*; and hence it seems to possess a particular power of exciting fire with the assistance of air.

In the formation therefore of fossil Salts, nature seems to have made use of a threefold acid; spirit of Salt; spirit of Nitre; and spirit of Sulphur; and that, in a very large quantity: with which she has likewise joined, a small portion of Sulphur; as well as water, and earth.

Of S U L P H U R.

The third class of Fossils, is composed principally of Sulphurs, though some *Sulphur* other bodies are referred thither likewise.

Sulphur, is a fossil body; hard in the cold, and easily reducible to powder; but in a moderate degree of heat running like melted wax; it may be raised by fire in a close vessel, intirely, and without any alteration; but if any air comes to it whilst it is melted, it will burn all away, with a blue flame, and a volatil fume, that is fatal to animals.

True Sulphur, as such, is found but seldom in the earth, and but in small *Quick* quantities;

quantities ; and there, it is either pellucid and yellow, like Amber ; or pellucid and red, like a ruby, which is called Sulphur of Gold ; or opake, yellow, grey, or of various colours, and these go by the name of *Sulphur vivum*, or Virgin Sulphur.

Common.

As to all the common Sulphur, which is sold in *Europe*, it is an artificial production, from the stone called *Pyrites* ; which nevertheless seems scarce to contain any naturally in it ; for no Sulphur rises from its *matrix* when urged by fire but an acid liquor like the acid of Vitriol.

This fossil matter however, if it is first prepared by Art, will afterwards by the assistance of fire afford a true Sulphur.

And this is effected by keeping the *Pyrites* for a considerable time in a strong fire ; where it softens, calcines, cleaves asunder, and discharges a perfect Sulphur.

But if there is true Sulphur actually existing in the *matrix*, then it is only melted down in crucibles, which are placed in such a sloping manner, that the Sulphur as it melts may distill into proper receivers.

Now the vein of the *matrix* both of Sulphur and Vitriol, is the same.

And hence, Sulphur is artificially made too, from Oil of Vitriol, Alum, or Sulphur *per campanam*, united with some pinguious vegetable substance.

Sulphur therefore has not improperly been called by the Artists, resin of earth.

When it has been purified by repeated fusions, from what rises to the top, or subsides to the bottom, it is poured into cylindrical wooden moulds, and is then the common Sulphur of the shops ; of which that of a lemon colour is esteemed the best.

Auripigmentum, or Orpiment.

Orpiment, in a great many of its properties very much resembles Sulphur ; it is friable ; fusible ; easily inflammable ; and then becomes hurtful from its disagreeable sulphureous smell, not from a volatile acid ; it is unactive, and innocent, and does not do that harm to the bodies of animals, as is commonly reported ; it grows red by fusion, and then yields a volatile matter of an emetic quality. This improperly goes by the name of yellow Arsenic

This native Orpiment melted in a close vessel is converted into a brittle mass, easily reducible to powder ; of a beautiful bright colour, like that of red Lead ; not very acrid ; nor of a very poisonous quality ; and yet both the ancients and moderns have called it Realgar, red Arsenic, and Sandarach ; and by this confusion of names have given occasion to some errors, that have happened in the Art.

White Arsenic of the moderns.

As for the white, chryselline, pulverizable Arsenic, which is such a strong poison, it is an artificial production of the moderns, not having been known above two hundred years ; and it is made in the preparation of Smalt from Cobalt, Flints, and a fixed Alkali : for whilst these materials are melting together, the flowers that rise in the operation are a crude white Arsenic ; which being afterwards put in fusion, with a strong fire, and in a close vessel, is the common white Arsenic of the shops. See *Kunkel, De Arte Vitriaria*, where he has given a cut of the furnace made use of for this purpose.

Modern yellow Arsenic.

If the Arsenical Flowers of Cobalt are melted down with a tenth part of common Sulphur, you have then a poisonous yellow Arsenic, which ought carefully to be distinguish'd from Orpiment, as it is a most insuperable poison.

But if you melt the same Flowers with a fifth part of Sulphur, you produce the

the poisonous red Arsenic of the Moderns, which we must take care too not to confound with the Arsenic of the Ancients, for the reasons already mentioned.

Hence therefore the modern Arsenic does not so much resemble Sulphur, but seems to possess a very particular quality peculiar to itself, and destructive to all animals: This the Ancients were not acquainted with; nor is it easily reducible to any *Genus* of known bodies: As it comes nearer, however, to Sulphur, than any thing else, it is referr'd thither. See by all means on this head, *Hofm. Obs. Phys. Chem.*

Those pinguious substances likewise, which are the natural production of the Earth, should be look'd upon as bodies that are near akin to Sulphur, inasmuch, as they contribute the greatest part towards its composition. Of this kind is *Petroleum*, whose name speaks both its nature and origin: This is expressed from melted *Bitumen*; drips down the rocks; is exceeding thin; very light; of a fetid smell, and perfectly inflammable; often swims at the top of fountains, and is so like a distill'd Oil in most of its properties, that many persons will have it to be prepared by a subterraneous Fire. This Liquid is often called *Bitumen*, tho' they differ in colour, smell, and transparency. Fossil liquid Sulphurs.

Napththa very much resembles *Petroleum*, but is more diluted, thinner, and brighter; it is vastly inflammable; continues burning a long time, when it is once set on fire; nor can it be easily extinguish'd: It is the *Floss*, or most pure and subtil part of *Bitumen*. Napththa.

The *Bitumen* of the *Latins*, and *Asphaltum* of the *Greeks*, is thicker than *Napththa*, and *Petroleum*; very tenacious; but in its first form nevertheless, somewhat fluid; so long as it remains in its natural state, it generally swims upon Water; it burns exceedingly furious. Bitumens.

This however being concocted, and dried by the heat of the Sun or Fire, or even by time itself, grows harder than Pitch; shining; ponderous; melts again in the Fire; will mix with any thing oily; is inflammable; and is then called, *Pix Judæa* or *Bitumen Judaicum*. Jews Pitch.

Pissphaltum, as its name indicates, is of a middle nature, between Pitch and *Bitumen*; black; earthy; fetid, and seems only in degree to differ from the former: And possibly it may be, either an artificial, or natural production, from a mixture of various fat substances with melted *Bitumen*. Pissphaltum.

This, when it is brought by nature to such perfection, as to become black; hard; earthy; capable of being cleft; smooth; fetid, and shining; it then seems to form the Jet-stone, or the *Lapis Thracius* of *Nicander*. Jet.

And again, if the pinguious parts of *Bitumen* happen to be mix'd and concreted with a rocky Glebe, or perhaps the *Scoriæ* of Metals, and forms a hard Mass; disposed in flakes or *lamina*; black; fat; cleavable, and inflammable; it then seems to produce the *Lithanthrax*, or fossil Coal, which must also be referr'd hither. Lithanthrax.

Ambarum, *Carabe*, *Succinum*, *Electorum*, Amber, belongs likewise to this class, which seems to owe its origin to a bituminous Sulphur; it both burns and melts in the Fire; it consists of an acid Salt, both solid and fluid, and a fossil Oil, which very much resembles *Petroleum*: Of this there are different sorts, as the white, lemon-coloured, yellow, black, and red. Amber.

The *Oleum Terræ* of the *Indies*, described by *Neubovius*, is seldom brought to us, being secured by the Princes in *Asia*; whether therefore this is a species of *Petroleum*, or *Napththa*, I can't pretend to determine. Oil of Earth. As

As for the common Oil which comes from the *Indies* under that name, I am inform'd, by a Gentleman perfectly acquainted with the affair, that it is nothing else but an exprest Oil from the Caco-nut, mix'd up with some medicated Earths, and therefore belongs entirely to the class of Vegetables. Is not what goes by the name of *Barbadoes* Oil, prepared too in the same manner?

Of STONES.

Stone.

A Stone is a hard Fossil; not ductile; brittle; fixed in the Fire; scarcely fusible by any Fire; nor dissoluble in Water.

By which marks it is perfectly distinguished from Metal, Salt, and Sulphur.

Stones may conveniently enough be divided into pellucid; semi-pellucid; and opaque.

Gems.

Pellucid Stones may not improperly be called Gems, and so reduced to a *Genus* under that name.

These, in all their properties, approach very near to Glass; tho' they exceed it in hardness, solidity, simplicity, and very difficult fusion in the Fire, and seem to consist of a most perfect fine Salt and Earth, intimately united together; as we see Ashes, which have a Salt in them, when melted in the Fire, run into Glass.

A transparent Gem, without the least mixture of colour, as nearly as possible resembles Glass.

The white, bright, pure Chrystal, that cuts Glass, is scarcely fusible in the Fire, is much like Glass, and is form'd by a certain particular concurrence and application of *Radii* and *Strata*, seems to claim the first place in this class.

The true Diamond, is an exceeding pure Gem; vastly hard; remarkably solid; perfectly transparent; very refulgent; of great value; coming nearest to the Chrystal which (perhaps of all Gems is the most perfect) and excelling every other body in its particular reflection of the rays of light. This will continue a very considerable time in a strong Fire, without being destroy'd.

The most pure of the Bastard-Diamonds, have somewhat of the nature of the true ones; but are softer; less solid, and less pellucid.

The white Saphir, is akin to the Diamond.

As likewise, the Oriental Amethist, when it is either naturally or artificially colourless.

The Topaz too, and Chrysolite, when perfectly free from colour, are nearly of the nature of Diamonds.

The true *Astroites*, which by a certain law reflects the solar rays from one common point, belongs likewise to the class of Pellucids.

The exceeding hardness, solidity, and perfect transparency of these Gems, make them vastly esteem'd.

Gems that are pellucid, but enrich'd too with some beautiful colour, seem to consist of the same matter with the former, but to have receiv'd likewise in their first formation, a tinge from some metalline in particular, or other fix'd fossil mixture, which by this means becomes intimately united with them: This the resemblance of their colours to the tinctures of Metals, and the artificial manner of making them, sufficiently evinces. To this class are referr'd chiefly,

The Amethist, Beryl, Carbuncle, Chrysolite, Granate, Jacinth, Opal, Ruby,

by, Sapphire, Emerald, and Topaz: Nor should, I think, the colour'd Chryf-
tals be left out.

The exceeding great value of these too arises from their vast hardness, re-
markable solidity, pure simplicity, and beautiful brightness of colour.

There is another sort likewise of a middle nature, betwixt Gems and opaque
Stones, which may therefore be called the Semi-opaque, and seem of a more
compound nature than the former: The chief of these are the following, which
differ in degree of opacity.

Agat. Sand. One sort of the *Astroites*. The true *Lapis Armenius*. The Toad-
stone. The Cornelian. The Chalcedony. The *Heliotropium*, or true oriental
Jasper. Jasper. The true *Lapis Lazuli*. The *Lapis Nephriticus*. The *Leucoph-
thalmus*. The *Malachites*. The Onyx. The *Sardius*. The *Sardonyx*. The
Selinites, and the Turquoise.

These too, are esteemed in proportion to their solidity, hardness, transparen-
cy, and the beauty of their colours.

The opaque Stones are the Eagle-stone. Alabaster. The *Amianthus*. The *Be-
lemnites*. *Gypsum*. The *Hæmatites*. Jasper. The *Lapis Judaicus*. The Touch-
stone. The Load-stone. White, Grey, Yellow, Brown, Black, Porphyrian,
Red, and Green Marble. The *Ophites*. The *Osteocolla*, Pumice-stone, Lime-
stone, Whet-stone, Mill-stone. Flint. The *Specularis*. Emeril, Talc, and
Tripoli.

These last are of very different natures; some of them vitrifying in the Fire,
and others turning into an exceeding fix'd calx.

Last of all come the fossil, native Earths, which for the most part are of a ^{Earths}
pinguious nature, and may with Water be work'd into a paste, whence they
are commonly called Boles; but are not dissoluble, either in Water, or Fire.
These are, Clay. The *Axungia Terræ*, or *Lunæ*. The *Cimolia*. Fuller's-earth.
The White Bole. The *Armenian*, *Chian*, *Etrurian*, *Lemnian*, Yellow, *Mal-
tan*, Red. Ruddle. The *Samian*. The *Selinusian*. All the seald Earths, and
the *Tocaviensis*.

There are some likewise of a poorer sort; as White-Chalk. Marl, and
Ochre.

Of SEMI-METALS.

The seventh class of Fossils, comprehends those bodies, which evidently
contain some true Metal in them; or at least something so like it, that it
may almost be look'd upon as Metal, and indeed, has been rank'd under
that denomination by very good Authors. These, if they are of the more sim-
ple sort, may properly enough be reduced to three species.

1. Semi-Metals, that consist of a true Metal, and a Salt, united together.

And these are generally called *Atramenta Sutoria*, *Calcantia*, 'Vitriols.

These now are observ'd to be of two sorts; one which owes its origin to Iron,
and is of a green colour; the other produced from Copper, of a beautiful blue.
As for the other Metals, they are scarce ever found in the Mines, in a state of
solution; their dissolving *Menstrua*, the Acids of Nitre, and Spirit of Sea
Salt, being never discovered there: And hence, you will hardly ever meet
with the solutions of Gold, Silver, Mercury, Lead, or Tin, either fluid or
concreted; at least in but a very small quantity.

Lead, it is true, may be dissolv'd by a weak Acid; but then the chemical Art informs us, how very difficult it is, to reduce it into Chrystals, as it presently gets rid of its acid, and turns into a powder, which goes by the name of Cerufs: And this is likewise true of Tin.

Every fossil Vitriol therefore that has hitherto been dug out of the Earth, owes its origin solely to Iron and Copper.

We don't deny, however, but that it is possible, that some particles of other Metals may be mix'd with Vitriol in a state of fluidity, and by this means become concreted with it; but that any other than Iron and Copper, has ever been actually dissolv'd by it, and so, equably and intimately united with it, wants hitherto confirmation.

This dissolvent, both of Iron and Copper, is that Acid, which when drawn off by a very strong Fire, goes by the name of the Spirit, or Oil of Vitriol; and is the very same that is separated by art from Alum, or collected from the fumes of burning Sulphur.

And indeed, both Vitriol and Sulphur, are generated, grow, and are procured from the same *Matrix*, viz. the Pyrites; which after it is dug, is exposed to the Air, freed from its great quantity of Sulphur, reduc'd to Powder, dissolv'd in Water, and then suffer'd to form its Chrystals about Sticks that are plac'd in it for that purpose.

It may readily likewise be produc'd from the *Misy* of the Ancients, by simple Solution, and ChrySTALLIZATION.

Hence therefore Vitriol is of five sorts. 1. The green; which owes its origin intirely to Iron, and Spirit of Sulphur: This is extoll'd for its medicinal virtues, and is the best for making Ink. 2. The bluish, which consists of a great deal of Iron, and a little Copper, dissolv'd by Spirit of Sulphur; for if you make a solution of it with Water, and then immerse plates of Iron into it, you will find them ting'd of a Copper colour; which makes it evident, that it contains a small mixture of that Metal. 3. The white, which seems to be very little different from the green, and possibly owes its particular nature, only to a greater degree of Heat, as we see in the factitious; for in every respect but its colour, it perfectly resembles it. 4. The *Chalcites*, true *Calcanthum*, or red Vitriol; and this too is exceedingly like the green, and may be resolv'd into the same principles; it seems compounded chiefly of Iron, and an acid of Sulphur, with, perhaps, a little mixture of Copper. 5. The *Cyprian*, or *Hungarian*, which is perfectly blue, and consists purely of Copper, and the same Acid of Sulphur. The *Sory* too, which is an exceeding acrid, hard, coarse, fat glebe, seems to be nothing but a grey or black concreted juice of Vitriol; and hence will produce a Vitriol, by the help of Water alone.

The *Melenteria* also, which is a grey, or black glebe, of a caustic quality, is of the same vein, nature, and family.

These all therefore, for their *Basis*, have Iron or Copper; for their dissolving *Menstruum*, an acid of Sulphur; whilst Water, which dilutes the acid, and disposes in a proper manner the particles of the Metal, gives them their figure and transparency: And hence, according to the different proportion of these three principles, may all the variety of them, deliver'd by the Ancients, be understood.

The native Vitriols therefore consist of Water; an acid Spirit of Sulphur; and

and the Metals, Iron and Copper, mix'd in a certain proportion, and concreted into one mass.

2. Other Semi-metals are compounded of Sulphur and Metal, intimately united together: Of these the following are the chief.

Native Cinnabar, or the *Minium* of the Ancients, which is a composition of Sulphur and Mercury, fused and brought into union in the Mines, by some subterraneous Fire: This the artificial Cinnabar is a proof of. It is easily resolvable into true Sulphur and Mercury; from whence it appears, that there is in reality abundance of Sulphur in the Mines, which owes its production intirely to nature.

Sulphureous
Semi-me-
tals.
Cinnabar.

The *Stibium* of the Ancients, the *stibum* of the Greeks, and Antimony of the Moderns, consists of a true fossil Sulphur, and another matter exceedingly resembling Metal; which, could it be render'd malleable, would be truly of a metalline nature, and be a seventh ductile Metal: But it is universally acknowledged, that this manner of purifying Antimony, has not yet been discover'd. Mr. Boyle however, asserts, that by some secret methods, true fluid Mercury has been produc'd from it: And indeed, every modern dabler in the Art pretends to it. It is fusible in the Fire, and makes other Fossils melt with a great deal more ease than they would without it.

Antimony.

Being brittle too itself, if it is mix'd with bodies that were ductile before, it will render them brittle.

And again, if it is put among bodies that are fix'd in the Fire, by its volatile Disposition, it will make them volatile also; scarce any one being perfectly excepted.

It very much too increases the brightness and beauty of Gold.

And lastly, in its nature it seems nearly to approach to white Arsenic.

Bismuthum, *Bisemutum*, Bismuth, is akin to Antimony, and consists of *Ami-* Bismuth.
na, or flakes disposed one upon another; in its white, bright colour, it resembles Silver; it is harder, and less friable than the former; nor ductile under the hammer; has evident marks of Sulphur in it; and by the action of an acid upon it, lets fall a bituminous matter; it is less fixed in the Fire than Metals; and being mix'd with them, renders them more volatile and friable.

Zinetum, Zinc is very much like the former, but less friable.

Zinc.

3. To this class of Semi-metals, may be referr'd all fossil, chrystalline, stony, or earthy bodies, which have a mixture of true Metal in their composition; of which sort some are found interspersed thro' the veins of most Metals.

This class therefore will include a very large number of bodies, out of which we shall only take notice of the following, which are the most remarkable.

The *Lapis Armenus*, *Cyaneus*, *Lazulus*, which is a smooth blue Stone, spangled with golden stars, and is said to contain a great deal of Gold.

Lapis La-
zuli.

The *Lapis Hæmatites*, which abounds with a metalline substance; is exceedingly like Iron; and sublimed with *Sal-Ammoniac*, smells very strong of an aromatic Sulphur, for which reason some persons have called it *Aroph*, or *Aroma Philosophorum*.

Lapis Hæ-
matites.

The Loadstone, which has a particular tendency towards Iron, is almost of the same colour, and very much of the same nature.

The Mag-
net.

Ochre too, perhaps, may come into this tribe, as it appears to be a precipitation of Iron from chalybeate Waters.

Ochre.

From what has been said then upon this head, we may be able to form a just notion of the principles of Fossils; for upon examination it appears, that they may be reduc'd chiefly to Mercury, Metallic Sulphurs, Salt, Combustible Sulphurs, Earth, and Stones; tho' it must be confess'd, that these are vastly different, if they come to be nicely examined in particular Fossils. We learn farther too, that they contain an acid Salt in them, which is exceedingly active; besides which, they are acted upon by no other moving power, but Fire.

Of VEGETABLES.

The next kind of bodies that come under the consideration of Chemistry, are Vegetables, or as they are commonly called, Plants.

A Plant in general.

By a Plant now we mean a Hydraulic body, which contains different sorts of juices, in various vessels, and by some external part of it, so adheres to another body, that through this part it is capable of drawing in the matter, both of its growth and nourishment.

By this definition then, we evidently see the difference between a Plant, and the fossil substances afore described; and that whether you consider the variety of its solid parts; the different nature of its juices; or its whole composition together, as made up, both of solids, and fluids.

The Root.

And again, the external part called the Root, which attracts its nourishment from the body to which it is join'd, sufficiently distinguishes it from every Animal we are hitherto acquainted with.

The solid parts of Vegetables are a mere Earth, so fastly united together by a tenacious, oily, glutinous matter, that they cannot be separated from one another, without the assistance of an open, flaming Fire.

The vessels of Plants, as they are exceedingly different in their make and position, so they are also in their contents and virtues.

The business of the Root, is to fasten the Plant to its soil, or (in which sense only we have here to consider it) to take in its nourishment; and hence sometimes, its whole surface is observed to perform this office; as we see evidently in the Mushroom and Puff.

For this purpose therefore, it consists of an infinite number of apertures of vessels dispersed through its whole surface, by which the nutritious juice is suck'd in, and so receiv'd into its vessels, and by these convey'd through every part of the Plant. These vessels may not improperly be compared to the Mesenteric Lacteals, and other absorbent veins in Animals.

This juice, however, at its first reception into Plants, is not of the same nature with the Plants themselves, but crude, and of the nature of the bodies, by which they are sustain'd and nourished. These now in general, seem to be either Earth or Water; which upon examination we shall find, receive again, sooner or later, the very same matter which the Plants had before drawn from them: For whether they are produc'd in the Waters, or on the Earth, when they come to die, they drop again into the same Waters, or Earth; or else are dispersed into the Air, whence, in form of Dew, Mist, Snow, Hail, Hoarfrost, and Rain, they descend again into the bosom of the Earth. Hence then it appears, that the Earth is a Chaos, of past, present, and future bodies, from which all receive their birth, and to which all do certainly return again.

The Water, Spirits, Oils, Salts, and whatever lies hid in the bowels of the Earth,

Earth, are put into motion, by subterraneous, artificial, and celestial Fire ; by which means they are rendered capable of being mixed with Water, and consequently of being applied to the roots of Vegetables, that are inserted into the Earth.

The Water again, of the Sea, Rivers, and Lakes, receives, as the Earth does, the bodies that float about in the Air ; and contains besides a variety of other matter, which it washes off from the Earth.

These crude Juices circulate through Vegetables in the greatest quantity, and with the swiftest motion in the Spring-season, and are then particularly observed to be watery, thin, and inclining to the acid ; as the liquor, that upon incision distils from the Birch, Walnut-tree, or Vine in the month of *March* demonstrates.

Afterwards however, as they are propelled through the various organs of the Plant, from the make of the Plant itself, from the effects they have impressed upon them by the Fire in the Earth and Heavens, from the changes of Moisture, Drought, Cold, and Heat, and lastly from the vicissitude of day and night, and the various seasons of the year, they are by degrees concocted, and made more perfect, and in particular parts of the Plant putting on different natures, become the proper Juices of the Plant.

The Leaves from the make, number, and fineness of their vessels, receive the most subtil of the Juices, and in a very large Surface expose them almost naked to the Air, which various causes renders very active ; here therefore they undergo very great alterations, and being perfected according to their particular natures are returned back again to the Plant ; the Leaves performing the same office in Vegetables, as the lungs do in Animals, as we learn from the elegant Observations of *Malpighi*.

The Juices that properly belong to the Leaves themselves, are the honey Dew that is spread over them in summer nights, a wax that oozes out of them, Manna, and the *Thereniabin* of the *Arabians*, which being put into motion and concocted by the heat of the Sun, are condensed by the Cold of the succeeding night, and so may be gathered from their Surface.

Afterwards the Cups, *Petala*, or Leaves, *Stamina*, and *Apices* of the Flowers, bring the Juices thus prepared by the Leaves to greater perfection, and impress upon them, more certainly, that distinguishing character, which is peculiar to the Plant ; as well as fit them for producing, preserving, and nourishing a new Embryo : this certainly, the affinity between the Leaves and Flowers, their near situation, the origin of the Buds, and the make of the Flowers, induce us to believe.

Here is generated that fragrant, reviving, almost vital *Aura*, that Flowers in their perfection so delightfully breath forth ; which, probably, by its prolific odour may be grateful to the Embryo : this is certain, that it is a very pure, and most excellent liquor, and if it is mixed with any thing else, loses it former beauty and excellence.

In the Flowers too is produced true honey, which oozes out into receptacles that provident nature has joined to the bottoms of the Leaves : this the Bees suck up, convey into their little bags, distil into their combs, and then secure with wax.

On the *Apices* of the *Stamina*, and on the *petala* there is observed likewise a wax,

wax, which the Bees scrape off with their rough feet, roll up into balls, dispose under the hinder part of their bodies, and so carry to their hives, in order to form and close up their combs.

The Seed.

The fruit, is the repository of the Seed, and its contents. The Seed, is the Embryo of the Plant, with a uterine *placenta*, or one, two, or more Cotyledons, to which the Embryo is fastened by an umbilical cord. The Cotyledons for the most part abound with a Balsam disposed in proper cells; and this seems to be Oil brought to its greatest perfection whilst it remains humid, and then lodged in these repositories. One part of the composition of this Balsam is oily, and tenacious, and serves to defend the Embryo from any extraneous moisture, and by its viscidty, to entangle and retain that fine, pure, volatile spirit, which is the ultimate production of the Plant: This the Alchemists have stiled, the *Spiritus Reſtor*, the inhabitant of Sulphur, the *Archæus*, and the servant of nature.

This Oil is never observed to enter into the vessels of the Embryo, which are too fine to admit so thick a fluid. The spirit however being quickened by an active power may possibly breath a vital principle into the Juices that nourish the Embryo, and stamp upon it the character that distinguishes the family; after which, every thing is changed into the proper nature of that particular plant. That this spirit now, is truly the efficacious part, is evident, for when that is gone off, the Oil that remains is quite vapid and unactive. 'Tis this that gives Plants their fragrant smell, and peculiar tastes; nor do their particular colours a little depend upon it. This Spirit *Iſaac Hollandus* called the *Quinta Eſſentia*, or quinteſcence of Plants.

Again, as the dry, brittle, fibres of Vegetables, require something to soften them, that they may bend easily without danger of breaking, they are provided with another sort of Oil running in its proper vessels by the sides of the woody Filaments; this may be discerned to drop from the middle of the wood, when it is heated, and by warmth, or length of time, is easily changed into a Balsam, and Refin.

The Bark.

This Oil, which is much less volatile than the other Juices, being concocted by the heat of Summer, is carried into the Bark, which like the *Membrana adiposa* of Animals is furnished with proper cells for its reception; in these receptacles it is first detained, and collected by the Cold of Autumn, that by thus forming a pinguious covering, it may secure the whole body of the Vegetable, from the injuries of Frost and Rain during the Winter Season. This always contains in it an acid spirit; which is a preservative against putrefaction. In this Oil of the Bark consists intirely the value of some of the *Asiatic* and *Indian* Plants; as we see in the Cinnamon of *Asia*, in the Bark of whole trunk and branches resides that choice Oil, which is so vastly valuable; whilst the Bark of the root affords us that wonderfully medicinal Oil, called falsely from its smell, Oil of Camphire. The Sassafras too of *America*, from its Bark yields us a very beautiful Oil; as in this part lies the vertue of that noble Febrifuge the Quinquina of the same country. Nay and the vertues of the *European* medicinal Vegetables likewise are very often to be sought for in the Bark; witness, the Caper-tree, the Tamarisk, and the Ash. In the winter time therefore, the Bark contains a large quantity of these Oils; whereas in the Spring, and Summer, the other Juices, which abound with a Water, Salt, and *Sapo*, proper to the

the whole Plant, pass through it in great abundance likewise; and hence at those times what it yields by a chemical Analysis, is very different from what is procured from it at others. The true Oil that belongs properly to the Bark, in its natural state is liquid, though by time and the heat of the Sun it will alter its consistence, and thicken into a Balsam. This again by longer time and a greater degree of Heat, being yet more inspissated, becomes a pinguious sort of a Resin; and by a continuation or increase of the same causes, acquires both the name, and nature of a Resin: This therefore owes its origin to the Oil, but is freed in a greater degree from its acid spirit; and it then melts, and burns all away in the Fire, may easily be dissolved and mixed with Oil, never suffers any solution from Water, hardens in the cold, and then loses its oily tenacity, and grows brittle. This Resin being yet further concocted, grows still harder, and then it is called Colophony. In this part of Vegetables, there is observed too, a thick tenacious Juice, which goes by the name of a Gum; this likewise will melt and consume in the fire, but in the cold, except it be extreme, retains its tenacity, and is intirely dissoluble in water. This oily Mucilage serves like a Pigment to cover over and defend the Buds of Trees, but will melt with a moist warmth, and easily runs from them, nor is ever so far hardened into a crust as to do any injury to the tender twigs.

About the bark of Plants, especially the umbelliferous kind, there is found still another Juice, which is a mixture of a Gum, and Resin, and therefore called a Gum-resin. Hence one part of it like a Gum easily melts in water; whilst the other is not at all affected by it, but in the manner of a Resin is readily dissolved and mixed with Oil: Of this sort are Aloes, Myrrh, Galbanum and a great many others.

And lastly every Plant contains in it a particular and peculiar Juice, which is produced by the whole efficacy of every part of the Plant successively applied to the crude Juices it is continually receiving. This therefore, when it is thus prepared, possesses the true nature and virtues of the Plant. This Juice can scarcely be reduced to any class of things yet known, and therefore must be looked upon as something perfectly singular.

If you examine the Leaf of the *Chelidonium Majus* in a live, flourishing Plant, you may observe a parcel of Fibres arising from the Stalk, which unfold, and disperse themselves all over the Leaf. You may perceive too that these are every where sending off branches, which joining with one another compose a curious kind of net work, which almost fills up the whole Area of the Leaf. If you gently now prick any one of these little ramifications, there presently issues out a Juice of a golden colour, which has the true virtues of the *Chelidonium*. In the same manner in the Spring you may procure from the common Aloe, a yellow, bitter Juice, which circulates through the Plant, in its proper vessels. The Poppy too upon making an incision distils a pure milky Opium. But here it is proper to observe, that these Juices, whilst thus simple, and separate, are vastly different from the mixture that arises from the confusion of all the Juices of the Plant together.

This then, Gentlemen, is what I thought proper to lay before you of the History of Plants, before I proceed to explain to you the methods in which they are managed by the chemical Art; nor do I see that more is necessary. For hence you may see how vain the endeavours of those Chemists must appear, who pretend

The proper
Juice.

pretend by their Art to be able to exhibit to you those parts of Vegetables in which their particular virtues consist, without a mixture of any of the other parts with them. If they would do this, they must certainly make use of very different methods from what they do at present, or else they will take a great deal of pains to no valuable purpose; but on the contrary will lead us into mistakes. And indeed, with submission to some famous Authors, I must take the liberty to declare, That Distillation, Fermentation, Putrefaction, and Combustion, produce such considerable alterations, in the particular *crasis* or constitution of Plants, and consequently in the medicinal virtues which depend upon it, that we ought to use a great deal of caution, and circumspection, before we can pretend, from these Operations, to determine the true causes of those virtues: Not that on this account this noble Science ought by any means to be neglected; Nay, for this very reason it should be more vigorously cultivated: For by this Art alone we are instructed, what such, and such particular Operations are capable of producing from any given bodies; and this alone corrects the error of those who practise it: These two advantages therefore, sufficiently recommend it; and by these alone it is capable of leading us to an infinite number of beautiful Discoveries.

The *Spiritus Rectior*; an exceeding fine Oil which is the true seat of this spirit; an acid Salt; a neutral Salt; a fixt, or volatile, alkaline Salt; an Oil mixt with a Salt in form of a *Sapo*; and a saponaceous Juice arising hence; an Oil which is most firmly united to an Earth, nor is easily separable from it; and lastly a pure simple Earth, which is the firm *Basis* of them all; are those principles, which Chemistry applied in a proper manner, has really discovered and produced from Vegetables.

Of ANIMALS.

Of Animals.

The third class of bodies, that have engaged the labours of the Chemists, are Animals, called the Animal Kingdom: But as of these the corporeal part only, has come under their consideration; hence when we speak of Animals, we mean only their bodies, and the parts of them, neglecting intirely their other principle, which is a subject of a very different inquiry. In this sense then, an Animal is defined a hydraulic body, which subsists by a constant and determin'd motion of humours through its vessels, and which contains within itself certain vessels, like the roots of Vegetables, by which it draws in that nutriment, which supports its being, and increases its magnitude.

Now the vessels, which thus perform the office of roots, are observ'd in almost every kind of Animal, and that chiefly in the small guts, going by the name of the lacteal and mesenteric veins. The food, and drink which Animals take in, being-applied to the mouths of these absorbent vessels, is the matter by which they subsist, and is the same to them, that the Earth is to Vegetables; and the concave *superficies* of the mouth, *oesophagus*, stomach, and small guts, which is in the inside of all Animals, are the parts to which the nourishment is apply'd, and through which they receive it. Hence then it appears, that Vegetables suck in their nutritious juices by external roots, Animals by internal; and that the Earth, which is the support of Vegetables, is always without them, whilst Animals receive their nourishment constantly from within. And this observation holds true, even in that kind of Animals, which naturally

turally grow, and are strongly join'd to some other body, as is evident in the Limpins, Oyfters, and other *Zoophyta*, whose shells adhering to rocks, or pieces of wood, contain an Animal firmly fasten'd to them by a very tenacious ligament: For these very shells, so long as the Animal lives, receive from this inclosed body, by certain vessels destin'd intirely to this office, their nourishment, support, and increase, whilst the Animal itself takes its food in at its mouth, and conveys it into its intestines, in the same manner as all others do, that are at liberty to move about from one place to another.

But farther, even the *Fœtus* of oviparous Animals, which reside, and are confin'd in their shell, till cherish'd by a pregnant warmth, and nourish'd by their own white, being still planted as it were in their yolk, they grow to maturity enough to break their shell, get out of their prison, and shift for themselves: Nay and lastly, those, whose eggs are lodg'd within the *Uterus* of the mother, to which they grow as it were by means of cotyledons, or a *placenta*, and umbilical cord, and are thus cherished and supported: I say, both these, tho' in regard of their Cotyledons, *Placenta*, yolk, umbilical cord, and *omphalo-hepatic* vessels, they then very much resemble a Plant; yet during the very same time, they take in at their mouths the liquor contain'd in the *Amnion*, convey it into their intestines, and by this means are nourished in the manner of other Animals.

Hence then, as we see evidently, that there is a great analogy betwixt Plants and Animals; so we perceive likewise, that there are some circumstances, wherein they evidently differ.

But farther, as we observe among Vegetables, that some are fix'd in the Earth, others fluctuate about in the Water, and a third sort grow in both; in like manner we learn from the Zoographers, that there are some Animals that live on the Land, some in the Water, and others, that to answer their different necessities, are equally suited either to Land or Water.

And lastly, as Plants, by the apertures of the vessels on their surface, draw in the humours that float about in the Air; so likewise the bodies of Animals are known to do the same.

But we shall yet again find a farther agreement between them, if we consider that they are both supported by the same kind of nourishment: For as Plants flourish and increase by the juices they draw out of the Earth, so Animals live either upon Vegetables, or the parts of other Animals, which upon examination, we shall find to have been fed with Vegetable juices: The matter therefore of both is the same.

And as the juice, which Vegetables receive from the Earth, is not of their nature, but crude, at its first reception; in the same manner, the food, which Animals take in, and the chyle which is produced from it, does not presently put on the Animal nature, but retains a considerable time the properties of those bodies from whence it was derived.

Indeed afterwards, by the surprising effect of the animal machine upon them, and the mixture of the juices with them that are already concocted, the crude ones by degrees are wonderfully chang'd, and in every part of the body put on new appearances, as will be taken notice of in its proper place. It is sufficient to our present purpose to observe, that the longer the food has been taken into the Animal, the oftener it has circulated through every part of its body,

and the greater number of its juices it has been mix'd and incorporated with, the more it constantly recedes from its own nature, and approaches to that of the body into which it is received.

The Spirits
in Animals.

Among the humours of Animals there is one that is vastly more subtil than all the rest; and this is called the exhaling Spirit, and seems to contain that singular quality which is peculiar to every particular Animal, and distinguishes it from every other. This we learn evidently from your Hounds, who will single out, and pursue over a great deal of ground, and through a vast confusion of tracks, that particular Animal which they first got fresh scent of, without any regard to the rest of the herd. We see the same thing too in their following their masters through common ways, where there is a great number of persons passing every minute backwards and forwards, and yet most certainly finding them out. Hence therefore it appears, that these *Effluvia* must be exceedingly subtil, and perfectly distinct from every thing else. These seem to be of an oily nature, or to reside in a most subtil vehicle, which owes its origin to an oil; as the analogy of things, and the rest of their properties induce one to believe.

Their Water.

Water constitutes the greatest part of the animal fluids, as in reality it does of most others; and indeed, it is so intimately united even with their most solid parts, that there are scarce any of them that are intirely without it; as the chemical Art has long ago informed us.

Their Salt.

There is a Salt too discovered in them peculiar to the Animal Kingdom, besides those Salts which they take in with their food, which from the power of the body suffer no alteration.

Now this Salt was never observed to be a fix'd one.

Nor yet so volatile, as ever to exhale from the body of the hottest Animal, so long as it continued in a state of health.

However, if for a good while you apply to it a degree of Heat, little greater than that of boiling Water, it will become intirely volatile.

Again, no person living, has ever discovered this Salt to be acid, unless it happens so, from things of that nature, which the Animal had received from without into its body.

Nor lastly has it ever appeared by any experiment that it is alcalious, so long as the Animal is in health, nay, nor even when it is sick; for upon a very careful examination that I made upon some urine, which had been retained five days in the body by a disorder in the urinary passages, I found, that even in that time, it was not become of an alkaline nature.

The same, however, by putrefaction, or a greater degree of heat, will be changed into a perfect alcali; but whenever in its natural state, by inspissation, and letting it stand undisturbed, you can artfully reduce it into little glebes, it appears to be a Salt different from every one that we are yet acquainted with: It comes nearest, indeed, to *Sal-Ammoniac* of any, but still, in some of its properties, it differs from that too; for *Sal-Ammoniac*, if put in a strong Fire, will be all raised without undergoing any alteration, whilst that which is drawn by Fire from urine, which is the *Lixivium* of the animal Salts, becomes immediately and intirely alcalious.

In short, after a great many experiments made on purpose to determine the true nature of this animal Salt, as it really exists in sound bodies, and acts there by

by its own peculiar vertue, it appears to be of a mild disposition; possessing a saponaceous quality from an Oil that is united with it; being a kind of middle Salt, between a fixt and volatile one; having not the least mark either of an Alkali, or an Acid; being easily, however, resolvable into a volatile fetid Oil, and a volatile alkaline Salt, and hence very much disposed to putrefaction.

Nor let any one be here led into a mistake by the fixt Salt, which is produc'd from the ashes of urine when burnt in the Fire; for this is nothing else but the Sea Salt, that was first taken into the body, which is able to bear all the actions, and powers, of the animal machine, without suffering any alteration in its nature.

And to the same cause do we owe that small quantity of acid, which after so much trouble, and with so strong a Fire we are able to extract from human blood; for it certainly appears to be only an acid Spirit of Sea Salt that was united with an Earth, and is now forced out by this excessive degree of Heat.

And hence Animals, in whose food there is no mixture of Sea Salt, have neither this fixt Salt in their urine, nor latent acid in their blood.

The Oils which upon careful examination Chemistry has discovered in Animals are of a very different nature: Some, for instance, are so subtil, that they'll bear to be mixed with Water, and become volatile with a small degree of heat, in which respect they very much resemble the spirits of Vegetables, in their natural state; but they differ vastly from those which are produced from them by the help of Fermentation.

There is another sort of Oil, which contains but a very small quantity of Salt in it, and is of an exceeding soft and smooth nature, serving to lubricate and supple the more rigid parts of the body: This in the cavities of the bones, is called marrow, in the *Membrana adiposa*, fat; in both which it is collected, and reserved for proper uses: It is this, that helps to sheath, and soften, the sharp humours of the animal body; and 'tis this that has sometimes been observed swimming upon the top of blood.

Again, there has been discovered another Oil which differs from the former, being concreted with the animal Salts, and so rendering them of a saponaceous quality, peculiar to the animal body: This, if you separate it, appears of a different nature from those already mentioned, being more acrid, fetid, and volatile.

There is yet a fourth kind of Oil, whose office is firmly to unite together the Elements of the solids, but so, as still to leave them a requisite degree of flexibility. This was originally form'd, and always continues in intimate union, with these Elements of Earth, not suffering itself easily to be separated from them: This dissolution, indeed, a strong Fire will effect, as well as putrefaction produced by a long continued action of the Air, Water, or Heat upon it; for then it becomes volatile and flies off, leaving nothing behind it but Ashes, which easily moulder away. Whenever this Oil is alone, it always discovers itself by an intolerable noisome smell.

But of all the Oils that are discovered in the animal body, there is none so wonderful as that which is drawn from their inspissated juices, when they are exposed for a great length of time to an exceeding strong Fire, and goes by the name of *Phosphorus*. This naturally takes fire in the Air, and burns away, leaving a fixed, acid, fluid behind it.

Earth of
Animals.

Earth of
Animals.

In the last place, there is found in Animals an Earth likewise, which serves as a *Basis* to the whole body, connects all the other particles together, and retains the fluids within their proper bounds.

This now differs very little, if at all, from the pure Earth of Vegetables; for whenever you separate them carefully, and examine them nicely, they appear to be perfectly alike. A plain proof of this we see in the docimastic Tests, and the little Furnaces made use of in assaying of Metals; for nothing is fit for this purpose, but a most simple earthy matter, that will neither melt in the Fire, nor run into Glafs: But whether now you procure this from the Ashes of burnt Plants or Animals, if you do but take care to separate it perfectly from every thing else, it equally answers the end: Nor indeed in the Earth thus procur'd, does there seem to be the least difference in any of its properties.

Their che-
mical Ele-
ments.

Thus then I have explained to you the principles, which enter into the composition of the animal body; those at least which Art has been able to discover, and lay before us; nor has there hitherto been observed any greater variety.

'Tis idle, however, hence to imagine, that the most accurate mixture of these Elements together, after they have been nicely separated, will ever produce the natural humours from whence they were extracted: On the contrary, the composition will most certainly be vastly different: For in every part of the animal Body, we find the humours of so singular a nature, that every one appears perfectly distinct from all the rest. The particular seat, for instance, of the bitter Bile is in one place; that of the Hepatic in another; the Seed is formed and perfected in its own proper organs; whilst another part gives being to the animal Spirits; the Chyle again of the Stomach, Intestines, Mesentery, Thoracic Duct, *Vena cava*, Heart, Lungs, and Arteries, is different in every one of these parts of the Body; not to mention the Milk, Fat, Lymph, *Serum*, Saliva, Blood, and Urine which are produced from it.

From what has been said then, it plainly appears, that there is an extraordinary agreement between the Elements of Animals, and Plants, so that the former seem almost to be made up with the matter of the latter; and likewise, that the chief difference between them, consists in the variety of their structure, and the swifter circulation of the aliments through the Animal.

And thus much for the Objects of Chemistry.

Actions of
Chemistry.

Chemistry then is engaged in the examination of the Bodies comprehended in the three Classes we have hitherto treated of. Now the alteration that is induc'd upon these by this Art, is owing intirely to motion: And here either a new one must be produc'd; or else one that was in being before, must be destroy'd, chang'd in degree, or alter'd in directions. These changes now happen sometimes to the whole Mass, its form remaining perfectly the same; and at others, to the particular Particles also, of which the Body is compounded. And on these very simple actions depend all the effects produc'd in the chemical Art; which, tho' they are so simple, yet from the vast number, and great variety of the constituent Particles of Bodies, they present us with an infinite number of new and surprizing-appearances: Nor can we, upon the most strict inquiry, discover any other causes of these alterations; nor indeed, is it possible to conceive, how the Art of Chemistry can effect any thing more. Let us consider, for instance, one single Body, and suppose both the whole Mass to

continue

continue at rest, and all the Particles of it one among another; will it not for ever continue the same without any alteration? Certainly, tho' all the powers of Chemistry should be exerted upon it, yet if no motion is excited, either in the whole, or any of the parts, they would leave it perfectly the same as they found it: But again, let us imagine a motion to be impressed upon the Body, so as to move the whole Mass, without inducing any alteration in its compounding Particles; why then too we shall have perfectly the same idea of the Body as we had before, except, that in every point of time it changes its situation: But now, should the Particles of the Body themselves be put into motion, then it's easy to conceive how an infinite variety of effects may be produc'd, which it is impossible for us to determine. The whole business of Chemistry therefore is to unite, or separate; nor is there a third thing that it is capable of performing; and hence all its operations may be reduc'd hither, without exception. Nor let any one be offended at this simplicity, as if it was impossible, that from this alone, should arise so great a number of very different and wonderful effects, which we observe no where else; for it is a known, and settled truth, that the simple mechanical union of different Bodies with one another, is capable of producing very surprizing varieties in the compound. The Arithmeticians too evidently demonstrate, that from a few Elements, dispos'd, and chang'd, according to the laws of combination, may be form'd an infinite series of new Bodies. And lastly, from the application of one Body to another, there often appears a new power, which before lay intirely concealed. If, for instance, no two Loadstones had ever been brought so near together, as to be within the sphere of each other's activity, we should never have had a notion of any such thing in nature as a magnetic Power: If again, no Iron had ever been seen in contact with the Magnet, certainly, the peculiar, and stupendous tendency that is observed betwixt these two Bodies towards one another, had never been discover'd: And lastly, if Iron touch'd by the Loadstone had never been applied to another piece of the same Metal, either touch'd, or not touch'd, what person living had ever been able to find out those hidden vertues, which in this case are the cause of such singular motions? But it will farther appear in the History of *Menstruums*, that a greater number of Bodies have this mutual tendency towards each other, which whilst they are at a distance is not perceptible, but upon their near approach, discovers itself immediately. From what has been observ'd then, it evidently appears, that by the resolution of compound Bodies into their Simples, and the composition of Simples with one another, may arise an infinite number of appearances, that we were not acquainted with before.

If a Body undergoes any alteration, but still retains the same quantity of matter, then, the figure only will be changed, or the surface altered; but even this so simple a change presently endues it with new powers. This we see plainly in the mechanical Art, which by changing the figure only can work the same piece of Steel into instruments of vastly different properties. Let an ounce of Steel, for instance, benicely formed into a Wedge, Knife, Dagger, Lancet, Sphere, Cube, Cylinder, Prism, Pyramid, and Cone; will it not then, under every one of these shapes, acquire new and peculiar powers?

On all these accounts, then, it is evident that the simplicity of the actions of the chemical Art, is no hindrance to their producing an infinite number of different effects.

And,

The power
of Bodies
from their
change of
figure alone.

And, indeed, it is of some consequence to conceive of this affair in a proper manner, as the Chemists are always prejudiced in an opinion, that their Art does really contain in it something yet more mysterious: If you examine their performances, however, you will perceive the truth of what has been asserted. Certainly, Calcination, Fixation, Vitrification, Sublimation, Fermentation, Putrefaction, Digestion, Depuration, and Adunation, with whatever other Operations they reckon proper to their Art, may be reduced hither.

A chemical Analysis does not exhibit the parts of Bodies as they existed in the Bodies themselves.

We must not, however, pretend to affirm, that those very parts, into which a Body may be separated, did really exist in the Body, in the same manner as they appear to us after their separation: For since the same powers that disunite these Corpuscles, may produce in them likewise a very great alteration, we shall often fall into an error if we suppose that the compound bodies in reality do contain these very Elements.

And, indeed, upon the resolution of Bodies, there often arises in the parts of them new virtues, which never discovered themselves by any effect in the bodies whilst they were intire; of which there is an infinite number of examples.

From both these reasons therefore it appears, that the Chemists are not altogether in the right, when they pretend to exhibit to us the first Elements of bodies, and think they can determine the nature of Compounds, from the knowledge they have of the Elements which by chemical Operations may be extracted from them.

Physical Atoms.

The examination of Bodies, it is true, informs us, that there are in nature certain Corpuscles, which when perfectly separated from all others, are not mutable by any cause we are hitherto acquainted with; whether it proceeds from their excessive, and more than adamantine hardness, which prevents any farther division or change; or arises from their very great subtlety, by which they are capable of eluding the force of all natural Powers.

When the resolution therefore of Bodies is carried so far as to reduce them to these fine Elements exceeding, there is a stop put intirely to any farther division, till these again are either united with one another, or with some other compound Body.

Scarcely ascertained by Chemistry.

These principles the Philosophers call, Elements of Bodies; and into these the Chemists have often asserted that they have reduced them; but they themselves confute their own opinions. We can't, indeed, but allow them, that the Elements of Fire, Air, Water, Earth, Alcohol of Wine, Mercury, and the *Spiritus Reſtor* of every body, and some other things, do appear exceedingly subtil, and durable, when they are absolutely simple; but that these particles can ever be collected, and exhibited to us pure and without any mixture, no Art hitherto has been able to demonstrate: And indeed, that there is nothing of this simplicity in the common chemical Operations, has long ago been past dispute.

The productions of which are seldom simple.

Fire perhaps, and that only, whilst it passes through Gold, or the like substances, may give us its Elements perfectly pure: But what person living can by any Art ever show us one drop of pure simple Water? and this in the rest is still more difficult. There is no need to mention Air, Earth, and the others.

Nay farther, the parts into which the greatest masters pretend to have resolved compound bodies, are not themselves of a simple nature, but mutable, and

and capable of farther division. This the Water, Spirits, Salt, Oil, and Earth extracted from animal, or vegetable bodies plainly evinces, Nay Alcohol itself is separated in burning into different principles.

And lastly, from a composition of the Elements, which the Art of Chemistry is capable of reducing bodies to, we can scarce ever again produce the original compound. This we have a proof of in the *Analysis* of Blood, Wine, and many other things.

Nor will these again united produce the same compound.

It is necessary therefore to fix some sure limits to our Art, which we must not exceed if we would avoid mistakes, and come at the truth. It must be allowed indeed, that certain chemical Operations, do always produce in Animals, Vegetables, and Fossils, some determined effects, which by their proper marks may be easily distinguished; but whether the things they lay before us did really exist in the same manner in the bodies themselves before these Operations, we cannot always rightly determine, without borrowing arguments somewhere else. Alcohol of Wine, for instance, by the help of a proper fermentation and distillation, may be always procured from certain sorts of Vegetables, in the same manner, and perfectly of the same nature. Nor was it ever possible to draw this spirit from any other substance whatever; nor from this, but by means of this double Operation. This liquor therefore, that the Chemist exhibits to us, was never discovered in Vegetables, till they had undergone both a due fermentation, and distillation. Hence too, nobody, can give any tolerable account of its matter, cause, nature, and virtues, besides the Chemist. The same thing holds true likewise in a great many other instances. This Art therefore we circumscribe within a narrow compass; on this account we assert it to be more valuable, excellent, useful, and necessary; and 'tis under these limitations that we are ambitious of professing it.

The just Conclusion from a chemical Analysis.

It appears then at length by the help of the chemical Art only, that there really is in every single Animal, and Vegetable, a kind of *Aura*, or Vapour, that is proper only to that particular body; and that this is of so subtil a nature, that it discovers itself only by its scent, taste, or some peculiar effects. This Spirit expresses the true genius of the Body in which it resides; and it is this chiefly that accurately distinguishes it from all others. The infinite fineness of this Vapour makes it invisible to the eye, though assisted by the most perfect glasses; nor can the most exquisite Art detain, and collect it by reason of its vast volatility: When it is pure therefore, and separated from every thing else, it grows impatient of rest, flies off, and mixes with the Air, and so returns to the grand Chaos of all volatile bodies. There, however, it still retains its own proper nature, and floats about till it descends again with Snow, Hail, Rain, or Dew: It then sinks down into the bosom of the Earth, impregnates it with its prolific seed, mixes with its fluids, and so at last unites itself again with the animal and vegetable Juices; and thus by this revolution returns into new bodies, in order to govern them and render them active. This Spirit, from its vast penetrability, exquisite subtlety, and prodigious volatility, the ancient Alchemists, who were certainly the top masters of the Art, and the most consummate Examiners of natural bodies, called the *Spiritus Rector*, or Governing Spirit.

The Spiritus Rector of the Alchemists in compound Bodies.

Now that this Spirit should be confined, and remain in its proper body, the all wise Creator has united it with a tenacious, durable Oil, which neither, Air, Water,

An Oil the true seat of this Spirit.

Water, or natural heat can easily dissipate; that by this means, being intangled in its viscosity, it might not too readily fly off, and so leave the body it was designed to govern, and moderate. Hence the same famous Authors loudly assert, that this Spirit resides in a Sulphur.

On which
account it is
more vola-
tile.

Of this Oil
the Spirit is
but an ex-
ceeding small
particle.

But prodigiously
active.

This wonderful
affair
illustrated
by an Ex-
ample.

Again, the Oil that thus serves to hold down and secure this Spirit is found to be more volatile than any other of the oily substances in the same body: and it seems formed of such a nature, to the end, that it might almost spontaneously exhale with its Spirit, as the body tends towards its dissolution; lest the Spirit which is so vastly useful, should remain inactive in the body after death.

And lastly, nature is so sparing in the distribution of this Spirit, that it allows to every Body but an exceeding small particle of it; which, however, is of so noble a nature, that it is abundantly sufficient. The antient Adepts have been bold enough to pretend to measure the quantity of this Spirit, and tell us that it is $\frac{1}{8200}$ part of its seminal Body; and that it is always found in this proportion in every seed in which it resides.

They assure us farther too, that they have observed it to be vastly active, and have learned by repeated observations that if you cherish it with a pregnant warmth, and support it with proper nourishment, it will still increase in activity, and in a wonderful manner continually acquire new strength for the production of an Offspring like itself. Hence they stiled it the Vital Spark, the Son of the Sun, the Spirit that nourishes within, with many other appellations of the like nature.

Now before I proceed any farther, give me leave to illustrate this whole affair by one single Example: To this purpose let us pitch upon a Vegetable, that evidently distinguishes itself from every thing else. Let it, for instance, be Cinnamon, that noble Aromatic, which is of so fragrant a smell, and so delightful a taste, far excelling almost all others, even the most precious. If you cautiously then, and according to Art, distill a pound of the choicest of this Spice with boiling Water, and take care that nothing of it be lost, it will yield you a milky Liquor of a fine smell and taste, and at the bottom of it, a small quantity of a red Oil, which is exceedingly fragrant, and possesses in a very great degree the true virtues of the Cinnamon; as indeed does this milky Liquor. If you then remove both these, and boil up the Cinnamon that remains with fresh Water, you will draw off a clear, watery Liquor, of an acid taste and faint smell, which is so far from containing any signs of Cinnamon, that it is so like many others, you won't be able to distinguish one from the other. Examine now the *Residuum* of the Decoction, and you will find it of a brownish red colour, an acid austere taste, without smell, or any thing that gives the least Indication of Cinnamon. The body of the Spice, indeed, that remains in the Decoction, you would swear to be Cinnamon, it represents it so exactly in its figure, and outward appearance; but upon farther examination, you will find that this is the whole it retains of this noble Bark, having lost all its former excellencies: And indeed, there is a little difference betwixt this, and any other Bark or Wood, that has been treated in the same manner.

The true peculiar virtue, therefore, of the Cinnamon is contained in the distilled Water, and the Oil that subsides to the bottom of it. If you let, now, this Water remain at rest for a good while in a close vessel, it will let fall an Oil, grow clearer, and become less aromatic: In the Oil therefore chiefly resides

resides this choice noble vertue. But again, if you separate this water from the subsiding Oil whilst it yet remains strong of the Cinnamon, and put it into an open bottle with a small mouth, the whole place will smell strong of Cinnamon, and in a little time you will have the Water quite vapid, without any of the properties of the Spice; and yet you will find that it has lost no more of its weight, than common Water would have exhaled in the same time, in the same vessel, and in the same place: The fine vertue therefore of this Water is really lodged in an exceeding small quantity of it, which consequently, must be extremely efficacious. Lastly, if you expose the Oil abovementioned to the Air in a wide-mouth'd glass vessel, there will be diffused through the whole place a most fragrant, delightful smell of Cinnamon; but in the mean while the Oil will lose its peculiar vertue, and after a short time there will remain an Oil, almost of the same weight with the former, but perfectly exhausted and deprived of all its original qualities.

Hence then it is evident, that all the proper aromatic vertue of Cinnamon resides in a very small quantity of Oil; and that even of this, it constitutes but an infinitely small part. And this particular demonstration will almost universally hold good.

The masters of this Science who have been most happy in their discoveries, tell us, that they have seen these Spirits even in Metals, and every kind of Fossil; that they are locked up in their proper Bodies, and confined there in their fixed Sulphur; and that whenever they can extricate themselves from their fetters, and become free, they then grow vastly active, insinuate themselves into other kind of Bodies, and are exceeding efficacious in the cure of diseases. But enough of this; if your curiosity about these things leads you any farther, consult the Adepts in these mysteries. For my own part, I don't choose to say any thing more upon this head, lest I should be suspected of recommending, and imposing on others, those things to which I myself am not equal.

The effects of this Art the Chemists have reduced principally to four *classes*; which are all produced either by adunation, or separation. When, for instance, they resolve a Body into any distinct parts which they collect and separate from it, they call this Operation extraction, and to those parts chiefly which are the most considerable they give the name of an *Extract*: Thus, when they draw from Wormwood the penetrating, bitter part only, they call it the Extract of Wormwood; as the most subtil part of Iron artificially separated from it goes always by the name of the Extract of Iron. Hither therefore are referred a great number of Operations, which may be performed on the same Body, as Distillation with Water, or without it; Decoction, and the inspissation of this Decoction through different degrees; Tinctures, let the *Menstruum* made use of be what it will; &c.

But when an Extract is drawn from several Bodies mixed together, in the same manner as the former was from a single one, it then changes its name for that of a *Clyffus*. And this appellation serves likewise for different Extracts prepared from the same Body, and afterwards mixt together; as when the Water, Spirit, Oil, Salt, and Tincture of Wormwood are artfully compounded into one mass, which possesses the united vertues of them all. Under this head therefore may be reduced a great number of beautiful productions of this Art; as the artificial Soaps, &c.

H

A Magistery

A Spiritus
Rector in
Metals and
other Bodies.

The classes
of chemical
Productions.

Extract.

Clyffus.

Magistery.

A *Magistery* seems at first to have signified among the greatest Masters of Chemistry the most excellent production, or masterpiece of their Art: For they tell us, they can change any simple Body into a matter very different from the former, and that commonly a liquid one, without any alteration in its weight, or the least separation of its parts. Thus, for instance, they assert they can reduce an ounce of Gold into a fluid of the same weight without the least admixture of any thing else; just in the manner as we see it when put in fusion by Fire. This, certainly, were we Masters of it, would be a most noble Art; but it lies hitherto out of our reach, unless you will suppose, that the effects produced by Fire are something like it. This however we must allow, that wax brought once over the helm, undergoes a surprizing alteration without any separation of its parts.

Elixir.

Lastly by the word *Elixir*, seems to have been meant the composition of different Bodies into one, so as perfectly to change their form, without making any alteration in their weight: And hence 'tis a kind of Magistery from several Bodies, as the former was from one. This *Paracelsus* asserts he has performed in Aloes, Saffron, and Myrrh, but conceals the only solvent which is able to effect this wonderful Operation; for which *Van Helmont* blames him, though he has not at all mended the matter himself. What reason is there however that we may not expect this from the chemical Art? Certainly, the preparation with tartarized Tartar, setting aside the skins of the Saffron, pretty nearly effects it: Nor do we make any doubt but that other Chemists are acquainted with better Solvents. It is certainly an argument of a weak mind to measure and limit other persons understanding by our own; though it must be confessed too, that the Artists by their too great pretensions very much lessen the opinion we should otherwise have of them.

I am well apprised that the terms abovementioned have been used in a different sense by very good Authors; but then, there are famous ones too, that have understood them in the manner, in which I have explained them. Let every one make choice of that, which pleases him best.

The service of the Art to Natural Philosophy.

The use of
Chemistry
in Physics;
As it makes
use of Fire,

And discover
that
which we
were not be-
fore ac-
quainted
with.

As Chemistry is engaged in the examination of all sensible Bodies, it is evident it must necessarily enter into, and be of use in all the branches of Natural Philosophy. And as Fire chiefly is the *Medium* by which it brings about the changes it produces in the Bodies that come under its management, in this very respect it must be of service to Physics, since Fire too, is the very instrument that Nature herself generally makes use of in the Operations it performs upon material Beings. As Natural Philosophy therefore is the knowledge of created Bodies with all their different modes of existence, it must certainly be promoted by the chemical Art. Give me leave to explain this a little more clearly. 'Tis the business of the Philosopher to deliver a true and accurate account of natural Bodies together with all their affections and properties. Now this knowledge cannot otherwise be obtained, than by carefully making observations upon all those Beings which the great Creator has formed within the compass of our senses. The first therefore, and indeed the principal part of this Science, consists in collecting together all those *Phænomena* of Bodies, which our senses are able to discover; and then reducing them into a natural

a natural History. Now there are two different ways of coming at these Observations: The first, when we regard the appearances of things only as they happen indifferently to all in the common course of nature without any design in the human mind towards their production; and this is not of so great service to the Art, as in this case it is chance only that discovers to us certain properties, which happened to be produced at those particular times: The other, when we designedly apply different Bodies to one another that we are well acquainted with, purely with a view to observe the new *Phænomena* that will arise from them. And this now, is of vastly more service to the Philosopher than the former: For, to mention no other reason, there are an infinite number of properties of Bodies, and those too very efficacious ones, that could never been found out in the common order of nature, but then only discover themselves, when the Artist with his Fire in particular, comes to examine them, either jointly or separately, on purpose to know what will be the result. And, indeed, Chemistry is almost the only Art, that seems suited to cultivate this second, and most valuable method of making physical Observations. 'Tis this that resolves compound Bodies into their simple parts, and after it has carefully examined them combines them together again, in order to know, what new appearances, and powers, will thence arise: 'Tis this, that separates, or compounds various Bodies, and then examines them nicely with a determinate, and well observed degree of Heat, in order to find out if possible, what it is in them that nature is chiefly engaged about: And lastly, 'Tis Chemistry that by these means discovering how it may exactly imitate the natural and common *Phænomena* abovementioned, hence truly explains, and exhibits to us the instruments by which nature so efficaciously operates; and thus pries into her most secret methods of working, and very often prudently directs and improves them to its own advantage.

Not only
taking notice
of common
*Phæno-
mena*,

But making
Experiments
with views
to new Dis-
coveries;

And that
more than
any other
Art.

A proof of this we have in Gunpowder, Phosphorus, liquors that upon mixture raise violent Ebullitions, and break out into flames, and an infinite number of other instances. We must, indeed, acknowledge that persons skilled in Mechanics, Hydrostatics, and Hydraulics, from certain general and universal properties of Bodies, may most certainly explain a great many physical Actions: But still, let them be ever so much masters of these Sciences, they will never hence be able to discover those effects of Bodies, which depend intirely upon the proper, and particular nature of some certain Bodies only, and which had never existed had it not been for those peculiar vertues. Whenever, for instance, the Loadstone, and Iron touched by the Loadstone, come near one another, what swift, and surprizing motions are immediately produced, which are no where to be seen in nature besides? Now that Chemistry is much more likely to help us to the knowledge of these particular qualities than any other Science is evident past all dispute; as this Art is vastly the best suited to the disposing of Bodies towards these kind of Discoveries. We may very justly therefore conclude, that of all Arts ours is the principal, and most efficacious in the promoting of natural Knowledge. A person that is master of this, will in reality make use of his Knowledge for the producing of its proper physical Effects, and not sit down satisfied with subtle words, or idle speculations. When the Chemist explains to you the nature of Glass, he at the same time teaches you the sure way of making it. If he talks to you

of Fermentation, he gives you an instance of it likewise to make it more evident. In short he never pretends to any thing more, than what he is willing to let you see he is able to perform. He don't trouble his head with fruitless Inquiries into ultimate causes; the present causes of things are what he studies, and what he teaches. He never invokes Demons, Hobgoblins, or Spirits, to his assistance; but performs all his Operations by the simple application of natural Bodies to one another. Nor does he concern himself at all about substantial forms; but, more to the purpose, takes pains to discover to us by their effects, those peculiar qualities and powers which nature has implanted in every particular Body; and then informs us how we may make use of them for the performing many surprizing Operations. Nor will he ever when at a loss, fly to, and take refuge in occult qualities; no, instead of that, by the help of his Art, he will search out, and discover those effects, which are falsely ascribed to those names, and then produce them into practice. The creation of the seeds of things, and the proper formation of every Body in its first original, he readily confesses he is not acquainted with; but takes a great deal of care to observe all the appearances that arise thence, and having faithfully collected them, makes a prudent use of them in the managing and changing of natural Bodies. These happy fruits is Chemistry capable of producing for the service of the Philosopher; and this Art, was it properly cultivated, would lead us to that knowledge of natural things, which the famous Lord *Bacon* so much wished for, and gave us a sketch of, and which afterwards, upon the beautiful design of that great Master, was improved and carried on by the immortal *Robert Boyle*.

The use of Chemistry in Physic.

The great
service of
Chemistry
in the medi-
cinal Art,

As it teaches
us the na-
ture of the
Solids,

And Fluids.

Now all that has been asserted of the usefulness of Chemistry in natural Philosophy, will hold equally true in the Art of Medicine: For this treats of the Human Body, and the powers, and effects of other Bodies upon it, neither of which can be thoroughly understood without the assistance of Chemistry. It will not however suit with our present design to enter into this affair too minutely, and therefore we shall only cursorily hint at some of its services in this Science. Chemistry, then, alone informs us, that the first Elements of which the solid parts of the Body are compounded, are a mere Earth firmly united together by an oily glutinous matter, which cannot be separated from them but by the extreme force of an open Fire. 'Tis this teaches us too, that Water also insinuating itself among these Elements, serves to bind them together, and being consolidated and concreted with them will not be expelled without a great deal of difficulty. 'Tis this farther that first explained to us the origin of this Earth, Oil, Water, and all the humours of the animal Body, from the Aliments it receives, these being first carefully examined according to Art; of which without this assistance we should have been intirely ignorant. And as for the parts, kinds, powers, and changes, observed in these humours, who can give any tolerable account of them without a thorough acquaintance with this Science? And lastly, as there is a certain degree of Heat that constantly accompanies a perfect state of health, which now a-days we are able to determine by the Thermometer; and as this when rightly discovered is the true measure of its active power: Chemistry far excels all other Sciences in explaining the proper effects of this Heat.

'Tis

'Tis true, indeed, that Mechanics, Hydrostatics, Hydraulics, and the other parts of Natural Philosophy, help us to the knowledge of a great many things that happen in the animal Body, whilst it continues in a state of health; but then, Chemistry leads us to a great many likewise, that we could not possibly have learn'd any where else: So that we are oblig'd to confess, that there are abundance of truths, and those of the greatest importance too, in the whole physiological branch of Medicine, that we could never come at, without the assistance of the chemical Art. But the greatest glory of this valuable Art consists in its being able to discover and correct those errors, which some whimsical dabblers in Chemistry had introduc'd into Medicine, as *Boyle, Bohn, Hoffman, Homberg*, and others, have by beautiful examples made appear. Those vain, trifling Chemists, were certainly in the wrong, when they pretended by their Art alone to explain physiology in all its parts; nor however are they less mistaken, who imagine they can do the same thing without it. No; let Anatomy faithfully describe the parts, and structure of the Body; let the Mechanic, by his particular science, examine the Solids, whilst Hydrostatics helps us to the laws of Fluids in general; and the actions of them, as they move through given canals, are explained to us by that beautiful Science Hydraulics; and lastly, let the Chemist add to all these, whatever his Art, when fairly and carefully apply'd, has been able to discover: And then, if I am not mistaken, we shall have a complete account of the physiological part of Physic.

In which it alone makes the most useful discoveries,

And corrects its own errors.

Nor is Pathology, as I apprehend, less beholden to the chemical Art than the former. Would you understand the causes, modes, and effects of the degeneration of the humours in the animal Body? Would you know how the juices are vitiated, when they move too slowly, are perfectly at rest in their vessels, or run out of them, and stagnate in the cavities? Or would you form a just notion of the alterations, that the Oils, Salts, Spirits, and Earth, that are mixed with our Fluids undergo, when they circulate through the Arteries with too great rapidity? You must go to Chemistry, and that only, for your information. Here too you will plainly discover, what Acrimony there is in the Body, how many sorts of it there are, whence it had its origin, and what are the effects of it after it is produced; which in vain you will seek for any where else. This will inform you farther, how the constituent parts of the Blood are compacted together, and by what means they are again resolved. And lastly, here you may learn the nature of *Pus, Ichor, Sanies*, virulent Fluids, and a putrid Gangrene, and what is the certain event of a *Sphacelus*. Now search after these things in any other way, and I am certain, with your utmost endeavours, you will never be able to give any tolerable account of them: Nay, the very Diseases of the Bones themselves cannot be rightly understood, without calling to our assistance the labours of the Chemists.

Assists Pathology.

But some persons will be ready to say, we allow you, indeed, that Chemistry may be of service in the physiological, and pathological parts of Medicine; but as to that part which treats of the signs of Health, Sickness, and Life, this was cultivated so accurately by the ancient *Greeks*, that there can be no room left for its assistance here. To this we answer, It cannot be denied, but that they did take an infinite deal of pains in collecting together the Signs of Diseases, and afterwards communicated them with as much integrity; but still, all their labours were confined to the examination of those things only, which

Of use in Semiotics.

which nature spontaneously offered to their observation. In this, we confess, they were surprizingly careful and accurate, even to that degree, that they scarce left any thing to be added by those that came after them. All these things therefore must the Chemist borrow from them, and them only, before he pretends to make use of his Art for gaining a knowledge of Diseases; and these he must gratefully acknowledge, as the effects intirely of their wisdom. But then, if we would rightly understand what every individual sign truly signifies, we shall be at a loss without the assistance of our Art, which alone is able clearly to explain it. This I could particularly demonstrate in every single instance, would the nature of our present business admit of it. But to mention only a few. The Ancients knew, that the more frequent Pulse of the Arteries, was a certain indication of a present Fever; and taught us, that the degree of it was to be measured by the number of strokes within a given time: By this means they tell us, the native Heat is increased, the radical Moisture destroy'd; and hence, according to the different degrees of it, Life itself is brought more or less in danger. The famous *Harvey* has farther inform'd us, that the quickness of the Pulse is owing to the more frequent reception of the vital Blood from the Veins into the Heart, and expulsion of it thence into the Arteries: And here their observations rested, nor serv'd us any farther. The Chemist, however, by the assistance of unexceptionable experiments, is still able to proceed, and teaches us, that by this increase of Heat from the celerity of the Pulse, the more fluid parts of the Humours must necessarily be dissipated, and the remainder inspissated; that the Oils will be dissolv'd and mix'd with the Blood, and by the attrition they suffer in the course of circulation, will become acrid, volatile, and putrid, and in this condition, being strongly press'd against the fine vessels of the Brain, will of consequence, wonderfully disturb it, nor will be easily again disengag'd from their union with Blood; that the Salts of the Humours will lose their natural ineptitude to motion, and become almost volatile; from an innocent, mild, disposition, will grow vastly acrimonious; and change their soft saponaceous quality into a fiery, corrosive one, and become, as some have asserted, a perfect Alkali. By this means, therefore, the Chemist comes to a right understanding of this Sign; and at the same time explains to us the use of it. With regard to the Urine, the Ancient Physicians were very careful in inspecting it, in order to discover, if possible, the internal disposition of the Body, and the more occult Symptoms of Diseases; and the Moderns are obliged to do the same: But of what service has this been to Physic? certainly of very little, as the judgment form'd from thence is very precarious: But let now a Physician, that is versed in Chemistry, examine it according to the rules of that Art, and how many, and how useful will be his discoveries? The quantity, colour, taste, contents, whether swimming at top, the middle, or subsiding to the bottom, and the spume, will make appear the true disposition of the Water, Salt, Oil, and Earth in the Urine, and consequently in the Blood at that time; and hence they discover to us the intimate disorders of the Humours, which are otherwise out of our reach, and serve as Prognostics, to point out to us the good or bad event, that in a short time is likely to follow. Here therefore, and here only can the Physician truly learn, both how to manage the present Symptoms, and foresee and provide against future events, in such a manner, that nature may be supported, and not left to sink under them.

them. 'Tis the Chemist, farther, that is alone capable of accurately distinguishing by their Signs, the true nature of sweat, *pus*, *ichor*, the *sputa*, and the excrements discharg'd by stool: Not that he is able to perform all this by the assistance of his own Art alone; but when to this he likewise joins a competent knowledge of Medicine, then it is he becomes truly qualified to discover, by the help of them both together, a great many things, which, otherwise, must certainly have escaped our observation. And it were much to be wished, that those Gentlemen of the faculty, who are such enemies to the Chemists, would consider this affair in a proper light; and then they would not so rashly condemn an Art, whose assistance may be of service to Medicine, but cannot possibly do it any prejudice. We confess, indeed, that some of the chemical Profession have done a great deal of mischief, by boldly venturing upon the practice of Physic, without sufficiently understanding it; but then, this was the fault of the Men, and not of the Science.

Again, its impossible for any person rightly to determine the diet that's proper for people in health, unless he knows what kind of corruption our meat and drink will naturally undergo, from the peculiar temperament of the Body that receives them, or the particular degree of exercise to which it is accustomed. In running-footmen, husbandmen, and all persons used to hard labour, fish, and fresh meats, putrify immediately from the violent motion of their Bodies, if they are not eat with a good deal of Salt; For such therefore, brown Bread inclining to be sowerish, Corn food, Milk, and Fish or Flesh dried in the Air or Smoke, and well seasoned with Salt, or Vinegar, is the best food; as Water, or stale small Beer, is the most proper drink: For since, by this excessive motion, the Bile, and the whole mass of Blood, necessarily tend towards putrefaction, this must be guarded against by those foods, which by their acidity, saltiness, or firmness, are least disposed to this kind of corruption. On the contrary, your pale studious persons, who sit long at their books, and deny themselves proper exercise, should eat only those meats that are easiest of digestion, and are soonest converted into the proper nature of the animal Humours: For these therefore, as Chemistry teaches us, the softer kinds of fresh meat, fish, and eggs, with a little salt, are the most convenient. And in short, if there's any Science that truly explains the nature of our Meat, and Drink, their Matter, and the method of pickling and preparing them; Motion, Sleep, the Excretions; and those passions of the Mind, that are of service towards the preservation of Health; it is, beyond all contradiction, that of Chemistry.

If we consider, lastly, the Therapeutick part of Medicine, we shall find, that the chemical Art is here of vast service also: For where shall we procure a suitable diet for our patients? Where shall we find Medicines proper for supporting of life, or recovering of health? Or where shall we be furnish'd with those Remedies that are capable of correcting things foreign, and hurtful in the Body, or expelling them out of it; or that will soften and sooth whatever is so sharp or stimulating? I say, how shall we come at all these, except by suitable helps, which Chemistry chiefly explains; which that alone digests in order, and best adapts to their proper uses? And indeed, it would be nothing absurd, should I assert, that it is this Art that most accurately points out to us those methods, by which we may learn from the Symptoms of the sick, whether, in what manner, and by what methods, we ought to act, in order to secure

Nor less in
Dietetics.

But principally in
Therapeutics.

and establish the life of the patient, and to correct or remove both the cause of the Disease, and the Disease itself. And here give me leave to recommend to your reading those things I formerly wrote, *de Methodo Medendi*, for the use of young Physicians.

Now the truth of what has been asserted, is confirmed by the authority of the great Lord *Verulam*, who by experiments, being thoroughly convinced of it, every where strenuously recommends the chemical Art, as proper for the fully completing every branch of Medicine. I might mention too the illustrious *Boyle*, who in his elaborate pieces, *The Sceptical Chemist*, which he himself enlarg'd and illustrated, *Of the uncertain success of Experiments*, *Of specific Remedies*, *Of the history of human Blood*, *Of the usefulness of experimental Philosophy*, *Of the mechanical production of Qualities*, and a great many other Tracts, has evidently demonstrated the use of Chemistry, in every part of Physic. It is needless sure, after these two, to mention any body else: However, for your farther satisfaction, you may consult the *Philosophical Transactions* of the *English*, and the *Memoirs de l'Acad. roy des Sc.* of the *French*; and there you will see how industriously this Art has been cultivated for the improvement of the knowledge of Medicine. But the *Ephemerides* of the *Germans* are particularly stor'd with elegant arguments to the same purpose. It is, however, our great misfortune, that the most expert and learned Physicians, have very seldom been thoroughly acquainted with Chemistry; as on the other hand, the greatest masters of Chemistry have hardly ever had a true notion of Physic, to the great detriment of both these noble Arts. *John Bohn*, and *Fredric Hoffman*, indeed, excell in both; and by this means distinguish themselves above all the rest, and deserve the highest praises. I don't mention with these *Otto Tachenius*, and *Francis de le Boe Sylvius*; because out of an excessive, and rash fondness for the chemical Art, they would not allow it to be the servant of Medicine; but judging more from their own inclination, than the nature of the thing, would have it her mistress. Whatever I have been able to collect from this Art, that may be safely, and usefully applied to Physic, you have, in a little Treatise I wrote *De cognoscendis & curandis Morbis*, and in my *Materia Medica*, which I published afterwards.

Usefulness of Chemistry in the Mechanic Arts.

Chemistry
of service to
Mechanics.

By which are commonly understood those Arts, that are cultivated and performed by manual operation, and which are perfectly different from that mechanical Science that is the business of the Geometrician, which explains the powers of Bodies, from the properties that belong to Bodies in general. To this latter, Chemistry is of no manner of service; but the former, which consist in the managing, and changing of Bodies, are very much promoted by it.

To Paint-
ing.

The Art of Painting, which by Colours can, to the life, truly express all visible objects, and hence is able to represent the most beautiful parts of the creation, and transmit them down to posterity, is of so fine and noble a nature, that it has always been honoured with the regard, and esteem of Princes. Consult on this head *Junius*, in that vastly laborious work, *De Pictura Veterum*. Now this, tho' it receives the assistance of a great many other Arts, yet in that part, which consists in the preparation of beautiful, and durable Colours, Chemistry very far excels them all: A few examples of this will be sufficient. The Pigment, called the *Ultramarine*, which is of so charming a blue, and infinitely lasting,

lasting, is prepared from the *Lapis Lazuli*, intirely by the help of Chemistry. The common Blue Smalt likewise, is a beautiful production of the same Art. See *Antonius Neri*. L. VII. 115. and Dr. *Merret's* Notes upon the same. What is it that the greatest masters of Painting are fonder of, than a fine durable Green? Why the lovely Ultra-marine Blue, mixt with a holding Yellow, will give you one that will retain its beauty for many ages. Was it not therefore for Chemistry, Painting would intirely want these two delightful Colours.

What shall we say of those Colours, called *Laccæ*, which are chemically prepared by coction, and precipitation? Do not these, by their brightness and clearness, give Pictures a vast deal of lustre and beauty? But for these, we are intirely indebted to Chemistry, as you may see in the same *Neri* L. VII. 116. 120.

Not to mention Cinnabar, Orpiment, Ochre, or that Preparation of Bones that the Painters make use of, which is made by calcining them in a close vessel to an intense Blackness. It appears therefore evident, that tho' the Arts of Chemistry, and Painting, are in their nature perfectly different, yet this, without the assistance of the former, would want its greatest ornaments: Nor indeed, could the Painter well do without it; tho' the Chemist stands in no manner of need of the Art of Painting.

The industry of the Chemists has discover'd an invention, by which they are able to incrustate Metals, Gold in particular, with most pleasant, beautiful Pigments, which shine like Glass, and are compos'd chiefly of a metalline or glassy Matter, and a most penetrating fix'd alkaline Salt. These, they call *Emausta*, *Amausa*, *Esmailades*, *Smalta*, Enamels; which by the brightness, and elegant variety of their Colours, are vastly agreeable; nor will any length of time destroy them. Consult again the famous *Neri* in all his *sixth Book*, and you'll think your time very well employ'd; but more particularly *Isaac Hollandus*, who has treated so largely and finely of this noble Art, which vies with the most magnificent tessellated works of antiquity. It is certain, the fair Sex are indebted to it for most of their valuable ornaments. In Enamelling.

There is yet a third sort of Painting, viz. that upon Glass, which is exceeding beautiful, representing its figures in Colours that are wonderfully strong, and at the same time transparent. A noble instance of this surprizing Art, we have in the Windows of a Church at *Tergou*, in our Province of *Holland*, which now-a-days can hardly be imitated. For formerly they were masters of a particular method, by which, after they had laid their Pigments on the Glass, they could; by the assistance of Fire, vastly heighten their Colours, and dispose them to a perfect transparency, and at the same time make them penetrate into the very substance of the Glass, without running beyond their proper lines, or confounding themselves in the least with one another. And indeed, I don't see that any thing can possibly be invented more curious, and ornamental, for the decorations of Courts, and Churches. We have not, however, a great deal of reason to hope, that this Art will ever be again retriev'd, unless the Chemists will diligently employ all the productions of their Art, in order to discover it. In staining of Glass.

Akin to Painting, is the Art of Dying, which consists chiefly in tinging In Dying. Silk, Cotton, Flax, and Wool, with beautiful Colours, and so furnishes us with curious Garments, Tapestry, Banners, &c. Now this Art depends principally

cipally upon three things. First, the materials to be dy'd must be perfectly clean'd, that they may easily suck in, and retain the Dye; which is done by soaking, beating, and scouring them with various *Lixiviums*. And here, putrified human Urine, the acrimonious Salt of Ashes, divers sorts of Soaps, and the Gaul of Animals, are of principal service. By these the viscous kind of Glue of the Silk-worms, that firmly adheres to the threads of the silk, which are always double, is diluted and wash'd off, by which means they become pure, and fit to receive their Colours; and by these the fetid oily impurities of the Wool, and the tenacious greasy matter, which has long been concreted with the Flax, is intirely discharged. Now in the choosing, preparing, and applying all these materials, the knowledge of the skilful Chemist is of a vast deal of service, so that he is continually improving them by the discovery of something new, and useful. The second thing requisite in Dying, is a proper preparation of the Dye, that it may perfectly penetrate into the substance of the thing to be dy'd, and then may retain its beauty without any alteration. *Cornelius Drebbelius* of *Alcmar*, in our Province, a man of remarkable integrity, and so perfectly skill'd in the most profound parts of Chemistry, that he was rank'd amongst the Adepts, and was in great esteem with one of the Kings of *England*, besides other things, left behind in writing, a particular method of dying Wool of a bright flame Colour; by which secret, *Kustelaer*, his Son-in-law, afterwards got a great deal of money. The rich Colour of Cochineal may be heighten'd by Spirit of Nitre, till it is perfectly bright as Fire; but then, by its Acrimony, it too much corrodes the Wool; you may soften it, however, by the assistance of Tin, and then you have a Dye that is no ways injurious either to Silk or Wool, whose beauty is exceedingly durable. The third thing necessary in Dying is fine Colours; and those our Art is capable of procuring. I remember, as I was formerly shewing a famous Dyer some liquors prepared from a solution of Copper, he seem'd surpriz'd at the elegance of the appearance, and declared he would give any thing for those Colours, were it possible to make Cloth take them in their proper strength and brightness. And no wonder; for in the Azure, Violet, and Green, Colours from Copper, which at the Will of the Artist are in a moment made fuller, or paler, there is such a vast deal of beauty and variety, that any person, who had the Art of Dying Wool, Silk, Linnen, and Cotton, with these Colours, in such a manner as to make them hold and not fly off, might certainly get an immense sum of money. It is therefore past all dispute, that the knowledge of Chemistry would be of great service to the Dyer, since by the help of it, he might be continually improving his Art by new and beautiful discoveries.

In making
Glass.

But if there's any Art that is greatly beneficial to mankind, it is certainly that of making Glass. 'Tis this, that by the Polisher's assistance, so comfortably helps the defects of our Eyes, and lengthens out our pleasure of reading, even to great old age. 'Tis by this alone that we are secured from scorching Heat, and piercing Cold, kept free from Dust, and preserved from the inconveniency of the Wind, in our Houses, Coaches, and Ships; and at the same time have light enough perfectly to distinguish the Objects about us. Pure Glass does not easily stain, and when it is, may be clean'd again with all the ease imaginable. This exposes to our view the things it incloses, and keeps them for ages; nor makes any alteration in them, or rarely suffers any from them.
And

And indeed, whatever is preserved in a Glass vessel, that is perfectly closed, and intire on every part, becomes immutable, and incorruptible. Glass eludes the power of all corrosives, even the *Alcabest* itself, if there ever was any such thing, which it is said it is able to confine, whether it boils in it, or agitated by the Fire flies about in it; whereas the *Alcabest* dissolves every thing else into a pure Water. Glass is the principal instrument in the Art of Chemistry; is of a very ancient invention; was cultivated chiefly among the *Egyptians*; in the time of *Tiberius* was rendered malleable; and is at present, and has for some ages past, been made in the greatest perfection among the *Venetians* and *English*. And certainly, was it not for its great abundance, it would be more valuable than any kind of Metal. Now the choice of the Materials for this noble work, the artful preparation of them, and the proper mixing, melting, and bringing them to their greatest purity, depend so much upon Chemistry, that they really receive no assistance any where else, but hence are capable of daily improvement. From Flint, Sand, and Stones, are made the various kinds of Glass; and the different methods made use of in the burning, and calcining them, in order to reduce them to a *Calx*, make a vast deal of difference in their beauty. The diversity of the Ashes too, as they are procured from Plants of various kinds, will make a considerable alteration in its goodness. That made from a pure, acrid, fixt alkaline Salt, melted with the best sort of *Calx* of Flint-stones, is of all the finest and most perfect. And here, the more there is of the Salt, and the less of the Flint, the more fine and perfectly transparent will the Glass be: But then its charms are not of long continuance, as it is very ready to crack and flaw, either by Fire, or Water, by which means it loses both its beauty and transparency: It is apt too to damage things that are put in it, and very often quite spoils them; as Tea, which in a green Glass suffers no manner of alteration, in the most beautiful sort loses all its vertue. For our business therefore we always choose the green Glass, which is most durable, and is composed of a larger proportion of Sand, and a lesser of Salt, kept melted for a considerable time in a strong Fire. But these hints are sufficient; as you may consult upon this head, the valuable *Antonius Neri* of *Florence*, in his Book *De Arte Vitriaria*; the famous *George Agricola*, in his seventh Book of *Fossils*; that celebrated *Englishman*, *Dr. Christopher Merret*, in his observations and Notes upon *Neri*; and *John Kunkel*, who, at the vast expence of that truly generous Prince, the Duke of *Brandenburg*, brought this Art almost to its greatest degree of perfection; as appears by his commentary upon *Neri*, which he publish'd at *Leipsic* in 4to, in the year 1679; but more especially in the Tract *De Gemmis Artificialibus*, which is annexed to it.

There is another kind of Glass, that is transparent likewise, but at the same time so enriched with some beautiful Colour, that it almost vies with the brightest natural Gems. This noble invention now owes its origin to the chemical Art, and truly imitates nature, by intimately mixing the infinitely divided particles of Metals with the purest, and most perfect Glass; and by this means, giving it a lasting beauty. So that, in reality, there are scarce any stones, valuable on account of their Colour, whose agreeable appearance this Glass cannot be made to resemble. And indeed, should ever any person happily improve the Art of Glass to that degree, as to be able to increase its weight by Fire in a sesquialter proportion, we may then, by the assistance of Metals, make

In making
artificial
Gems.

artificial Gems of the same brightness, with those that are the true production of nature ; for the more dense and solid the pellucid matter is, the stronger will the colour of the Metal appear, that is dispersed through it : But as this condensation of Glass has hitherto been beyond the reach of Art, the substance of the artificial Gems is less dense than that of the natural ones ; and consequently the vibrations of the rays of light are more weak and languid, and want that vividness that is peculiar to the other. Some have, indeed, attempted to increase its weight by a mixture of Lead ; but then, it grows too soft. It is well worth while therefore, for the lovers of Chemistry, to employ their utmost endeavours for finding out a method of condensing of Glass ; for it certainly will abundantly recompense all their labours. There is yet a second thing requisite to the perfection of artificial Gems, and that is, the giving Glass such a degree of hardness, that it may not by wearing, lose the lustre of its polish, but retain its beauty, and put on the incorruptible nature of a natural Unit. And lastly, when we have communicated to it a proper solidity, and hardness, we must afterwards colour it with some rich metalline Tinctures ; and then, we might by Fire form the Mass thus prepared into multangular Bodies, that would excell the natural Gems, both in magnitude, and variety. For we have an incredible number of the choicest colours, that might be either intimately mix'd with the Glass when 'tis in fusion ; or be disposed upon its surface, and by the assistance of Fire, be made to penetrate into its substance, if that ancient Art should again be restored. Now it is Chemistry alone that furnishes us with these three principles, on which the artificial way of making Gems intirely depends, and gives us frequent opportunities of improving this beautiful Art.

As the greatest masters, however, in the chemical Art, have never been able to give artificial Glass a requisite weight, and hardness, some of the subtlest of them took it into their heads, that the most clear and perfectly pellucid fossil Chrystal, might possibly answer the same purpose ; for this being naturally very heavy, and hard enough to cut Glass, wants only colouring with some metalline Tincture, without destroying its transparency, or the beauty of its polish, to make it nearly resemble natural Gems. This therefore they attempted by heating the Chrystal red hot, and then extinguishing it in colour'd Liquors ; but the flaws that were occasion'd in this operation disappointed their expectation, which would otherwise in some measure have been answered. See *Boyle of Gems*, p. 19. 44. Others have endeavour'd the same thing, by cementing Chrystals with different kinds of Metals, and not without success ; for the Metal being afterwards melted, and forc'd up by Fire, penetrated intimately into their substance. And it is possible, that some time or other, there may be discover'd some artificial Pigment rich with a metalline Colour, which being incrustated over Chrystal, may by Fire, be perfectly diffused through its whole Mass, and give it a most beautiful brightness. Now these methods, which seem the most likely to produce something considerable in this elegant Art, depend so intirely upon Chemistry, that there is not the least reason to expect any assistance in this affair from any other Science.

In Metal-
lurgy.

As for the Art of Metals, the knowledge of Chemistry is so necessary to this, that it seems to claim it wholly to itself. I don't mean here that Art, which consists in the boasted production, and transmutation of Metals ; of this I shall

I shall honestly relate those few things, I have, upon mature deliberation, been able to discover, when I come to discourse of the usefulness of the chemical Art in Alchemy. In this place I would be understood to treat purely of that Art, which teaches us how to prepare Metals for the ornaments and uses of life. Gold, for instance, is frequently of a pale colour, and that from a great many causes; now this the Chemist, by a cement, or *Regulus* of Antimony, can heighten in the Fire to a most beautiful yellow. This we see at present in the gold coin of *Holland*, which far excels all other in its particular lustre; for which, we are beholden to the curious and peculiar skill of the master of the Mint. The same Metal, when it is perfectly pure, is from its natural softness unfit for coining; but, tempered with a proper alloy of Copper chiefly, or Silver, it excellently answers that valuable purpose. Silver, in like manner, is too soft, and ductile, either for coin, or the common uses of life; but is easily rendered fit for both by a due admixture of Copper. 'Tis needless to mention Brass, which is a composition of Copper and *Lapis Calaminaris*, and much resembles Gold in the brightness of its colour; or that Metal made of Copper and Zincq, called Prince *Robert's* Metal, which being nicely gilt vies in lustre with the most beautiful *Obrizum* Gold. As for the Art of Gilding the baser Metals with Silver, or Gold, how curious is that Art, and how valuable? These now are all instances of the service of Chemistry in the metallic Art; and though they are few indeed, yet they sufficiently demonstrate what an infinite number of effects might be produced, would the skilful Chemist make a proper use of his Art in the various compositions of Metals. Nor even in this affair don't Medicine receive some advantage; witness the cups made of *Regulus* of Antimony tempered with other Metals, which communicate a medicinal quality to the Wine that is put in them. And it is ten thousand pities the famous *Van Helmont* should have been so unkind to his poor fellow creatures in distress, as to conceal from us the Art of making a particular Metal, which he tells us made into rings, and worn only whilst one might say the Lord's Prayer, would remove the most exquisite hæmorrhoidal pains, both internal and external, quiet the most violent hysteric disorders, and give ease in the severest Spasms of the Muscles. p. 745. § 39. 'Tis right, therefore, I think, to prosecute Inquiries of this nature; for there is very frequently some hidden virtues in these Compositions; and we may make a vast many Experiments of this kind without any danger or inconvenience. Metallurgy again, that consists in the knowing and distinguishing the fossil glebes as they are found in their subterraneous veins, and thence producing pure and perfectly distinct Metals, depends intirely upon our Art. This is plain, even from this consideration, that Chemistry owed its origin principally to Metallurgy; and this, by modern inventions, it now again vastly assists and improves. But we need not stay much upon this Head, if you will carefully consult *George Agricola*, *Lazarus Erkerus*, *John Rudolphus*, *Glauber*, and others, who have for the most part borrowed what they have, from these. For your greater satisfaction, however, I will give you three or four Examples. It is a known thing among the Chemists, that it is very easy to prepare a matter, which being mixt with Gold, Silver, and other Metals will render them so volatile, that they may in a glass vessel be brought over the helm with a moderate heat. And experience as certainly evinces, that there is very often in the native Glebes that

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contain

contain the richest Metals a certain substance, which, when the fossil is exposed to the management of the Fire, carries off a great deal of the Metal with it, to the prodigious loss of the Owners. There is, for instance, a volatile, noxious Sulphur very often united with Gold and Silver, which disperses vast quantities of these Metals into the Air whilst they are only torrifed by the Fire. But the industry of the Chemists has discovered certain methods, by which they can at once render these volatile Glebes so fixt, that they will bear fusing in the strongest Fire; and by this means the Metals will be separated from every thing else. You know that *Regulus* of Antimony, mixt with a double quantity of the corrosive Sublimate of Mercury, will by a gentle Fire be changed into a fat substance that is extremely volatile; and that this by a moderate degree of heat will rise in deadly Vapours, and by the repeated action of the Fire become at last a limpid Oil that fumes spontaneously. This, I remember, I have frequently both explained to you, and demonstrated before you. Pour, now, upon this Oil an equal quantity of pure Water, and it will presently in a surprizing manner turn of a white colour, and precipitate a white metallic *Calx* of Antimony, which is so capable of bearing the Fire, that it may be intirely melted into a mass like Silver, and is the finest *Regulus* of Antimony that Art can produce. Let us therefore, from this simple Experiment, learn to mix Water with the volatile Glebes, and observe whether by this manner of treating them, they won't yield a greater quantity of the richer Metals than they did before. Iron likewise being added to these Pores in their calcination, oftentimes so absorbs the Sulphur, that it cannot carry off the metalline Particles along with it. And the fixt alkaline Salts too have saved a great deal of treasure by subduing and resolving the Sulphurs, or Acids, which being dispersed through the metallic substance made it volatile in the Fire. The richest Silver Mines of *Peru* are unfortunately infested with a pinguious matter, which makes the Glebe of a volatile nature when it comes to the Fire, by which means there was formerly an incredible quantity of Silver intirely lost. But the Chemists have now instructed us, first, to torrify the Ore with a gentle Fire, then, to reduce it into powder and rub it with Mercury, afterwards to wash it in a proper manner with water, and lastly to collect the Silver together into one mass, by putting the matter thus prepared into a Retort, and forcing out the mercurial Particles with which it was united, and since this has been practised there has been scarcely a grain lost; by which means there is an infinite deal of wealth preserved, which would otherwise have been dissipated into the Air. The difficulty of perfectly separating Silver from the Tin that is found mixt with it, used to be a matter of great concern, both to the Miners, and the persons employed in the docimastic Art: But since we have learned from the Chemists that by the admixture of melted Copper the Tin may be easily disingaged, and carried off, we can collect the Silver pure from the ashes with a great deal of ease, and little expence. There are a thousand other advantages for which Metallurgy is indebted to the Art of Chemistry; but you don't expect that I should be more particular upon this subject; nor indeed will our present business permit it.

In the Art
of War.

Again, the chemical Art alone furnishes us with a great number of instruments of War, that were intirely unknown to the ancients, and which, indeed, are so destructive to the moderns, that we should have been happier without their discovery. But

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as the evil and restless spirits of some part of mankind are perpetually the occasion of War, and violence; hence 'tis absolutely necessary that we should be able to repel force by force, in order to defend and secure ourselves; and in this, money excepted, the whole stress lies at present upon the Inventions of Chemistry. In the twelfth century Gunpowder was found out by *Roger Bacon* in *England*; and with this he imitated Thunder and Lightning, but to the happiness of that age did not employ this wonderful discovery for the destruction of his fellow creatures. About two hundred years after, *Bartholdus Schwartz* of *Germany*, a Monk and Chemist, accidentally observing the sudden expansive power of this powder, whilst he was preparing it for medicinal uses, immediately made a trial of its surprizing force in an iron Tube, and soon applied it to the Art of War, and taught it the *Venetians*. And indeed the whole force of War now a-days consists so much in this chemical Invention, that by the help of this the weakest boy may overcome the most valiant hero; nor is there any thing, be it ever so strong, that is able to stand against its stupendous power. The great *Coeborn*, therefore, General of the *Dutch* forces, wisely considering the efficacy of this chemical Discovery, immediately changed the whole Art of War, and all the methods of defence; so that those fortifications which were formerly looked upon as impregnable, are now not able to secure the persons that defend them, or preserve them from danger even within their own walls. And indeed the power of this wonderful Powder, is yet more and more to be dreaded. As for that Powder which is compounded of Sulphur, Nitre, and the burnt *Fæces* of Wine, the force of it is so prodigious, I can scarce mention it without shuddering. Who can think of the violent explosive faculty of *Aurum Fulminans*, and not be astonished? When we mix the chemical Oils of the most fragrant Aromatics, with a liquor extracted from Salt of Nitre, we produce something vastly more powerful than Gunpowder itself, which spontaneously, without the application of Fire, rages in a most furious manner. And lastly, which it gives me pain to mention, let me here put you in mind of that melancholy accident, which happened in *Germany* from some *Balsamum Sulphuris terebinthinatum*, which being unfortunately quite stopped up in a Bolt-head, the glass burst by the heat of the Fire with a prodigious explosion, far superiour to any of the former. Heaven grant that the noble Inventions of this valuable Science may be no farther improved by the craftiness of mankind to the destruction of one another; the fear of which obliges me to conceal many things, I could otherwise mention, that are still much more pernicious, and detestable.

That the ancient *Magi* of *Asia* were men of superiour wisdom, I think is sufficiently agreed by the learned world. And that this name has not always signified evil Agents, Contrivers of mischief, and Slaves of the Devil, is evident from the *μάγοι ἀπὸ ἀνατολῶν*, mentioned by *St. Matthew*, who were famous for their knowledge of the Stars, and sincerely worshipped the true God, by whom they were accepted. That they were in great esteem too with the Princes of that country, in ancient times, and consulted in their most weighty affairs, we have related in abundance of places of History. And we find that *Zoroastres* himself, the King of the *Bactrii*, who was the founder of this sect, is chiefly extolled for his knowledge of the heavenly bodies, whose motions, and the principles of the world, he is said to have studied with a great deal of application. *Justin. l. 1.* For this reason therefore, as *Cicero* tells us, the *Persian* Kings were instructed

In natural
Magic.

instructed in the Art of Magic, before they were admitted to the government. *De Divinat.* I. 91. And he likewise assures us, that the *Magi* in *Persia* were looked upon as persons of great wisdom, and learning. *De Divinat.* I. 47. It happened afterwards that an illiterate set of men, greedy of fame and riches, endeavoured by their deceitful cunning, and juggling tricks, to imitate the profound knowledge of these Wise Men; but their frauds being often openly detected, the Magic Art came to be basely exploded; which has frequently too, though undeservedly, been the fate of Mathematics. The employment of the true *Magi* was to search carefully, and curiously into nature; by which means they often discovered things that were concealed from the observation of others, and which the all-wise Being designed as the proper rewards of laborious study and application. Hence the ignorant regarded them as men endued with more than human knowledge, which they imagined therefore they received by the intercourse and instructions of Dæmons, and for that reason paid them great reverence, tho' more out of fear than any real respect. And this they were the more naturally led into, as it has been a prevailing opinion of all ages, that there are two kinds of Spirits, the one good, the other evil; and that these being perfectly skilled in natural knowledge, and moved the one with love, the other with enmity to mankind, endeavour by their skill to allure them into their service, the good, in order to make them happy; the evil, with a design to make them miserable. Whether this way of thinking be just, or no, I do not here examine. The perfections, powers, instruments, and hidden faculties of nature, the production of supreme Wisdom, vastly, I confess, exceed my comprehension. By that little however which we do know, we are disposed to believe, that there lies hid in the bosom of futurity, an infinite number of things, that will some time or other be clearly revealed to mankind, of which at present there is not the least shadow of appearance. Who can deny, that there may be beings, who have a faculty of looking more intimately into nature than the most sagacious human mind was ever capable of? Who can demonstrate but that these Spirits, without corporeal assistance, may be able to get acquainted with Bodies, understand their powers, perceive the chain or order of causes, see things present, foresee things future, and know things that are past? Nor is there any absurdity in supposing, that these Dæmons may insinuate their thoughts into human minds; since we at present are no more acquainted with the connexion, and mutual intercourse of thinking beings, than we are with the number of different kinds of beings, that are endued with understanding, will and affections. Nay even the manner of motion's passing from the moving body into the body it strikes against, is more than we are able hitherto to explain. Will any person dare to assert that it is impossible for thin incorporeal images to fly about in a hollow empty form, that has in the open Air seen the Spectres reflected from a concave *Speculum*, which so strongly, and perfectly represent the dimensions, colours, and every thing that appears in the solid bodies, that one can't help being surprized even though one is aware of it; and yet if you offer to touch them, you find them a perfect shadow? And as our soul is united to a body, by whose assistance it perceives things without us why may not every one of these volatile *Species* have a spirit implanted in it, capable of penetrating, moving, and changing every thing? Whether these things are so, or not, I don't pretend to determine; 'tis possible
time

time may discover it. Nor will I assert, that there have been persons who by the assistance of Dæmons have been able to know, and do more, than they could have done by their own natural powers; nor yet will I absolutely deny it. 'Tis an argument of too much presumption and vanity in us, who scarcely know any thing, to take the liberty to speak confidently of things that are far above our reach. I would not have you imagine, however, that I design by this to persuade you to believe, a parcel of old wives fables, the reveries of idle persons, the stories of credulous ones, or the fictions of those that design to delude us. Nothing less! I am too sensible that it is with the ignorant chiefly that these things find credit; with men of sense very rarely; and that always the less, the more cautious we are, and the more circumspection we use, that we are, not imposed upon. As for the foretelling things future; the discovering of secrets; the raising the passions of the mind, and fixing them upon any object one has a mind to; the creating, removing, or asswaging distempers by numbers, words, signs, figures, inarticulate murmurs, charms, little images, a look, or laying on of hands; the changing one's self, or others, into different forms; the making persons invisible that are in your company; riding through the Air at one's pleasure; the giving life, sense, motion, voice, and affections to inanimate beings; the calling up of Ghosts, Dæmons, Spirits, and the Bodies of the departed; the mastering, driving away, and binding of Spectres; the obtaining of honours; the finding of treasures; the making money always return back again into its master's pocket; the rendering Bodies invulnerable; the getting the better of one's enemies; the fixing them like statues at one's pleasure; the ruling the Elements; the overcoming even nature herself, so that neither Fire or Water shall have any power over us; the raising meteors in the Air by a command; the taming and governing the most furious wild beasts, purely by incantation; and the producing ludicrous appearances only with a word; these, and such like things, are what the true *Magi* never pretended to, but are only the boasts of crazy-headed people, which the superstitious are apt to believe, and the wicked sometimes invent in order to delude the credulous, and get them into their power. Against such foolish notions as these, that famous Author, whom I have before mentioned with respect, *Roger Bacon*, wrote with a great deal of strength, and shews us that there is in reality no such magic Art in the world; nor does he believe there ever was. On the contrary, he carefully inculcates, that there do actually reside in natural Bodies, certain latent and hidden powers implanted in them by their Creator, by which as wonderful effects may be produced, as were ever ascribed to the borrowed assistance of the Devil: That these qualities however cannot be discovered without a very laborious, and diligent inquiry; but that when by assiduous Study, and proper repeated Experiments, they have been once found out, they may then, by a due application of them to one another, be made use of for the production of such things as, to persons unacquainted with these properties, will seem contrary to the laws of nature, and will therefore be concluded to be the effects of a preternatural power. And this kind of true substantial knowledge may properly be called natural Magic. This is that magical Art which I would endeavour to recommend; and this in reality is very serviceable to mankind, very entertaining to persons that are acquainted with it, and by its wonderful Operations very well suited to shew forth the praise and glory of the great

Creator. Indulge me a little, and I'll give you a few Examples of this, which intirely depend upon the chemical Art. Suppose an Author of undoubted veracity that lived a thousand years ago, should have told his posterity, that there was in his time a man who publicly gave out before a vast number of witnesses, that a prodigious tower, which they there saw at twenty furlongs distance, should at a certain point of time spontaneously rise into Air, and presently fall down again in ruins; and that it happened exactly as he had foretold; would not every one that read this look upon it as a fabulous story, or else, regard it as the effect of a power superiour to that of men, or even nature itself, and consequently ascribe it either to the Divine Being, or some infernal Spirit? And yet if you imagine that at that time there was but one man in the world, such a one for instance as *Mahomet*, or *Haly*, that was acquainted with the force of Gunpowder, and that he had conveyed a sufficient quantity of it under the tower, and according to the modern invention had artfully disposed a piece of clockwork in such a manner among it, that at the very moment of time that he had fixed, it should by striking a flint against a piece of Steel set fire to the Gunpowder; you see with how much ease he might have performed this surprizing miracle, by which he would certainly have gained so much credit, not only with the common people, but even with men of understanding, that he might have influenced their minds in what manner he had pleased. When the secret indeed comes to be discovered, our admiration ceases; and we then look upon these things as the production only of natural powers, which before we thought superiour to any magical Miracles that have ever been related. Not that even at this time the most sagacious person living can truly comprehend the cause of this surprizing effect; but we are falsely apt to imagine that we perfectly understand those things, which we see very frequently happen. It is possible in the same manner for a person to foretel, that in an hour's time there shall happen an Earthquake in a certain part of the earth, which shall at first send forth a prodigious black smoke, and afterwards burst out into crackling flames. People indeed that heard it would be apt to laugh at us; but then certainly they would be as much surprized when they found it to be true. And in order to this, take only equal parts of fresh filings of Iron and pure Sulphur, rub them together, and with a little Water make them into a paste of about fifty pounds weight, then put this a foot and a half under ground, and ram the earth hard down upon it, and your prediction will be fully compleated. Surprizing effect! that cold Iron, inactive Sulphur, and cold Water, only by being mixt together, should, under a weight of earth, be capable of producing Heat, Smoke, Fire, and Flame, without the least assistance of Fire. But again, there is a story of a Tutor, who after all other endeavours to no purpose, by a contrivance borrowed from Chemistry, happily reclaimed a noble youth, who by his dissolute life brought disgrace both upon himself and family, and seemed past all hopes of amendment; and this was in the following manner: - One night as he lay in the same room with this young Gentleman who was fast asleep, he got out of bed softly, and with some English Phosphorus wrote his name in large letters on a board that was at the feet of the bed, and added three words, intimating that if he did not immediately repent, he must expect to die in a very short time: When he had done, without disturbing his pupil he stole gently to his bed again, but then

then made a great noise on purpose to wake him, and laid himself down as if he was asleep. The youth presently started up in his bed, and listened attentively in order to discover the occasion of his surprize, but heard nothing except the snoring of the other, who feigned himself asleep; but looking accidentally towards the feet of the bed, he saw some letters shining with a blue light which vastly astonished him. Upon this, he calls to his companion, and shews him the writing; who making as if he knew nothing at all of the matter, professed that he did not see any thing; which so much the more increased his terrour. The servants who were not in the secret, were then called to bring in some candles, upon which the letters disappearing, they declared too that they saw nothing; and indeed the youth himself was astonished to find that the writing was vanished. The servants went away again, but left a candle which happened to shine upon the board; the tutor sets down by his pupil and persuades him to go to sleep, tells him 'twas only a dream, and then goes to bed himself, and puts out the candle. As soon as ever the room was dark, the youth no sooner looked towards the fatal place, but he again saw the same letters, at which being vastly frightened, he cries out, and begs his tutor to come to him; who then pretending himself to be afraid, confessed that he did indeed see the writing, and that not without a great deal of astonishment; and then took this occasion to admonish him sincerely to repent, in obedience to this Miracle, and calling for a candle spent the remainder of the night with his pupil, who was under great concern, and was brought by this means to a better way of life. Now this story, if it is true, as I have frequently heard it affirmed, is an Example of natural Magic from the chemical Art: If it is only a fiction, it is certainly a possible one, since such things may at any time be effected by the help of Phosphorus, as nobody that knows any thing of the matter will deny. If the power of Phosphorus be so far weakened by a soft Oil, that it may be applied to the skin without burning it; then the face being rubbed with this Oil will shine terribly in the dark; and yet upon the approach of a light the shining will intirely disappear; which being again removed, the countenance will regain its former brightness, than which nothing certainly can be more surprizing. Suppose now a person was to anoint his face, hands, hair, and beard with this sort of Oil, and then dispose himself in some dark place; would not the credulous vulgar presently imagine there was something in it celestial, angelical, or divine, and be ready to believe any thing upon such a one's authority? Give me leave yet to mention another thing, which you yourselves have been here often eye-witnesses to, and that is, the surprizing effect of mixing together two liquors perfectly cold, which in a moment boil up in the most furious manner, and burst out into a beautiful flame. Now if the thickness and blackness of the smoke, and the brightness of the flame is so astonishing in the middle of the day, would it not to appearance be vastly more terrible, if the Experiment was performed in the dark, when the flashes of the light must be abundantly more visible? And, indeed, if we compare this wonderful *Phænomenon*, with the stories that are told of magical Spectres, I verily believe we shall scarcely find any of them that will equal it. Now this is the effect only of one drachm of one of the liquors and two of the other; what therefore must be the event should pounds of them be mixed together? Certainly the force of the smoke, and flame,

would be infinitely great, nor any ways to be restrained, but would overthrow every obstacle that stood in its way, and destroy, and consume every thing about it with a Fire not to be extinguished. And which is still more surprizing, if the same Experiment is performed *in vacuo*, it acts with so much the more violence, and in the very instant of mixing, tears every thing to pieces, and flies about with a force superiour to the strongest Whirlwind. The *impetus* of this Fire is certainly of a vastly different nature from that which was raised about *Creusa's* head by *Medea*; for by the strength of this even the whole court might have been blown down and turned into ashes. But again, who has ever heard, or read of any thing so wonderful and terrible ascribed to the magic Art, as we have known effected by *Balsamum Sulphuris terebintbinatum*? which being closely confined in a Bolthead, and forced by a strong Fire, burst the vessel with a stupendous noise, and produced such strange and peculiar effects, that in all the extraordinary *Phænomena* I have read of Thunder and Lightning, I don't remember ever to have met with any thing that equalled them. See the *Observationes Physico-Chemicæ* of the famous *Frediric Hoffman*, lib. III. Obs. 15. where you will find an account of many things which you would have thought absolutely impossible to be effected by the powers of nature. Among others, you have there some very surprizing effects of Spirit of Wine, which a Cooper putting into a strong cask with some lighted Sulphur, and then perfectly closing it up, there followed a most violent explosion, that tore the vessel to pieces, and was the occasion of some accidents that are almost incredible. But lastly, when we see the skilful Chemist take a parcel of clean glasses, and in a moment's time produce all sorts of colours, and as suddenly destroy them, then renew them again, and vary them at his pleasure, does not this, to a person that never saw it before, or knew any thing at all of the matter, appear supernatural, and even greater than the power of Magic? There are an infinite number of other instances to the same purpose; but let these suffice to demonstrate the usefulness of the chemical Art in natural Magic. Give me leave, however, to trespass upon your patience a little longer, whilst I add a few more observations upon this subject. The Divine Being has created the human Species in such a manner, that those in particular, who are in some measure adult, and enjoy a perfect state of health, are capable of perceiving and understanding the changes and properties of the things about us, that have a power of producing some alteration in the Organs of our Bodies, and by this means exciting ideas in our minds. This is evident beyond all contradiction, let the immediate cause of it be what it will. Now the first time that this happens to us in our life in any extraordinary instance, it generally affects our minds in such a wonderful manner, that it engrosses all our faculties, and often gives us an infinite deal of pleasure; though sometimes indeed it proves too strong for our mortal powers, and quite overwhelms us. The *Illustrious Boyle* tells us a story of a man that was totally blind from his childhood, occasioned by a Cataract in each eye, which afterwards being happily couched by a skilful hand, he was instantly restored to his sight. But what was the consequence? Why, the man was at first so vastly transported with the pleasure of seeing, that his sensations were raised to such a degree, and his Nerves so strongly affected, that he narrowly escaped falling into a *Delirium*. They were forced therefore immediately to cover up his eyes, and afterwards

terwards to let in the light a little at a time, and thus accustom him to it by degrees ; by which means, never any thing like it happen'd to him afterwards.

For the same reason, the Author of Nature has wisely provided, that the aqueous humour of the eyes of children should be always turbid, and somewhat opake, when they are first born, and afterwards by degrees become pellucid. And in like manner the external orifice of the *Meatus Auditorius* is constantly closed up with a sort of callous membrane, and the passage itself has not its proper length and curvature, by which the force of every sound would be vastly increased; by which means the child, when it comes first into the world, is secured from any inconvenience that might otherwise arise from the noises about it. Afterwards, indeed, as it grows able by degrees to bear stronger sounds, the acoustic tube is lengthen'd, and the membrane drops off of its own accord. And here give me leave to observe, how imprudently those people act, who suffer the children of Princes and great men, to be exposed to the light of abundance of candles, and shock'd with the noise of cannon fired at a small distance from them, as soon as ever they are born. If persons therefore of this rank, should ever be committed to any of your care, as seems promising from your Genius's, and indefatigable application, be sure take care, that the tender infants are not injured in this manner; either by wholly forbidding it, or at least advising, that it may be put off till a more proper opportunity. But to return: You know that we are affected in a different manner by things we are used to, and by things that happen but seldom: Hence it comes to pass, that being deceived by custom, we are apt to think we perfectly understand the nature, and causes of the former, whilst we look upon the latter as something miraculous, and are ready to believe, that they cannot be accounted for by the common laws of Nature. Those appearances therefore, that fall frequently under our observation, tho' in reality we are perfectly ignorant of their causes, we readily call natural; and on the other hand, those, that offer themselves to us, in a manner quite uncommon, we conclude to be above the power of Nature. And hence, when we see any physical *Phænomena*, which are not produced by the natural Powers which we observe in those Bodies which we have chiefly to do with, but depend on the singular properties of some particular Bodies which we are perfectly unacquainted with, there presently arises in us a suspicion of Magic. Of this, give me leave to mention the following instance. Count *Furstemburg*, a military officer, coming one day into a shop, where they were filing some iron and brass, and seeing the filings promiscuously scattered one among another, he smil'd upon *Zwinger*, who was then at his work, and ask'd him in a joking manner, what he should give him to separate the particles of Iron and Brass perfectly from one another? *Zwinger* merrily answer'd, he would do it for a very small matter; nay, even for a bottle of wine. This being agreed to, he took a Loadstone, and applying it to the heap, with a sort of incantation, to amuse the Count, call'd the filings of Iron, which came leaping and running to the Stone, and left the Brass intirely by itself. The Count, who had never seen or heard of any thing of this nature, tho' a wise officer, and brave soldier, immediately cry'd out, that it was done by the power of the magic Art. See *Zwinger's Treatise*, 239. But lastly, and I have done, when we observe any uncommon changes in the appearances of the Bodies about us, which depend upon
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some qualities of those Bodies, which nature never discovers of herself, but which then only appear, when the Bodies have been properly prepared, either by art or accident, we are then, too, ready to look upon such *Phænomena*, as the effects of Magic; which the following example may serve to illustrate. If you take the very cold Salt of Nitre well dried, and mix it with half its quantity of the purest Oil of Vitriol, and then put this mixture into a Retort, and by the help of Fire force it into a dry Receiver, in form of a very red, volatile, acid, fiery Spirit, you will then have such a Liquor, as has never been produced either by Nature or Art, in any other manner than this, which was discover'd by *Glauber*. Again, take any of the choicest strongest aromatic Vegetables that grow in the hottest Climates, boil them strongly in pure Water, and confine the Vapour with a proper head in such a manner, that it may pass through a Tin worm every way surrounded with cold Water, and it will be condensed in form of Water, at the bottom of which you will find a fragrant heavy Oil, that perfectly expresses the qualities of the Spice from which it was distilled. And this Liquor too, is the sole production of this operation. Take now one part of this Oil, and pour upon it in a quiet vessel, two parts of the abovementioned Spirit, and there will immediately arise a most violent conflict between them, they'll puff up, cause a furious ebullition, and throw out a kind of lightening, that consumes every thing that is near it. Here then you see a *Phænomenon*, the causes of which are implanted in these Bodies, but in such a manner, that they never discover themselves, except they are first managed and prepared in the manner describ'd; and consequently, the knowledge of producing these extraordinary Motions, and Flame, depends intirely upon the three circumstances taken notice of; nor can they be effected in any other natural way. Hence then we conclude, with how little reason we can pretend to limit, and determine, the powers of created beings, whatever age we live in: For there may always lie conceal'd in the bosom of Nature, infinite numbers of properties of Bodies, vastly more wonderful than any that have been yet discover'd; nay, and even those things that in one age are vulgarly known, in the succeeding are frequently lost, and when in after-time they come again to be found out, are look'd upon and extoll'd as new and wonderful discoveries. But we must quit this subject, which would carry us to a very great length, were it accurately treated in the manner it deserves.

In Cookery.

How comfortably are the necessities of mankind provided for, by the Art call'd Cookery, which preserves and prepares our Food, for the easy support of life, and is as serviceable to people in health, as Medicine is to those that are sick. Now this, tho' exceeding ancient; nay, possibly coeval with mankind, may receive a great deal of assistance from Chemistry. The acid Liquor, for instance, drawn by Fire from Sea Salt, if it is diluted with a proper quantity of Water, wonderfully preserves Fish, Flesh, and other things that easily putrify, prevents their being corrupted, gives them an agreeable taste, fits them for the easiest digestion, guards them against the bad effects of excessive hot weather, and even cures the distempers that this heat is apt to produce. And hence it is of infinite service to Sailors that are obliged to go into those parts of the world, where the Water and Fish putrify, Flesh stinks, and Bacon grows rancid, with the extreme heat of the Climate. Upon this head *John Rudolphus Glauber*, who wrote some Treatises, *De Consolatione Navigantium*, *De Prosperitate*

tate Germanie, and others upon the same kind of subjects, deserves the highest commendation. He, in those informs us, how a man, without any trouble, may in a little vessel carry about with him a Liquor, which only being made use of to the quantity of a few drops, will answer very valuable purposes. There too he teaches us, that by proper solution, depuration, inspissation, and preservation from the Air, we may prepare a Liquor from corrupted Corn, now-a-days called Malt, a little of which contains a good deal of nourishment; and farther, how this, with a mixture of Wheat-flour, may be made into Biscuits that will keep a considerable time, and are very hearty Food. The illustrious *Boyle*, in that excellent Piece, *Of the Use of Experimental Philosophy*, gives us an account of some simple methods, borrowed chiefly from the chemical Art, by which Flesh, Fish, and Eggs, either fresh, roasted, or boiled, may for a vast while be preserv'd from corruption. And it is this Art that furnishes us with those Pickles, that will even correct and prevent the progress of putrefaction, after it is but just begun.

The juice of Grapes, Apples, and almost all summer Fruits, if you boil and inspissate it when it is fresh press'd, may be thicken'd into a durable Mass, a bit of which being again diluted with Water, will even in winter nearly regain its native sweetness; and that, whether it is prepar'd with Sugar, or without it. If this same Juice is press'd in the time of vintage, and suffer'd to ferment, work, and deposite its Lees, it then becomes good Wine; and here, upon examination we shall find, that in almost every step, from the beginning to the end, we are obliged to proceed according to the rules laid down by our Art: Nay, and even the faults which are apt to happen in the making, and which the Wine is liable to after it comes to perfection, are chiefly prevented, and corrected, by the helps we borrow from Chemistry. If it begins to fret again, inclines to be tart, or is growing foul, it is this Science that presently furnishes us with suitable Remedies; or If you would make it into Vinegar, this will teach you by what means you may effect it. The same Art too instructs us how to prepare Wine from all sorts of pulpos Fruits: Grapes, all kinds of Cherries, Gooseberries, Berberries, Currants, Elderberries, Pears, Apples, and the various sorts of Plums, are all, by the management of the skilfull Chemist, made to produce an agreeable Liquor, which truly deserves the name of Wine, and is with a little assistance equally grateful. And all these now are constantly observed to be of the same nature and efficacy; for they all agree in this general property, that the first Liquid that is separated from them by a gentle heat, is pregnant with Spirits, which will burn in the Fire, and may be diluted with Water; and this Liquor, when it is perfectly rectify'd according to Art, you will always find exactly the same, from which-ever of the abovemention'd Fruits it is produced. Nor has happy *Britain* any reason to repine, that in her soil Grapes won't ripen to that perfection, as to be fit to supply her with Wine, since Nature has so liberally indulg'd her with Apples, which with proper management yield a Wine, that in the fragrance of its smell, and gratefulness of its taste, vies with the richest of *Italy*, *Spain*, and *France*. Nor is the juice of the Grapes in *Holland* rich enough for this purpose; but then, they have a way of preparing the same from Currants, Gooseberries, and Elderberries, which is little inferiour to the produce of the hotter Climates. And lastly, from Herbs themselves, after being prepared by boiling them with

In making
Wine.

a gentle Fire, may be drawn a Spirit, tho' in but a small quantity, which is considerably strong. Now after all these are skilfully made, is it not the Chemist that teaches us to preserve them, and prevent a new fermentation by the assistance of the fumes of burning Sulphur, and at the same time to keep them fresh, and secure their flavour? 'Tis from the chemical Art that we learn how to soften Wine, when it is too rough by a small mixture of Salt prepared from the burnt *Fæces* of the Wine, and how to recover it, when 'tis grown tart by a proper addition of Crabs-eyes, or Chalk. And it was to the sagacity of the Chemist, that we were beholden for the discovery of that abominable practise which some persons made use of with their sharp crude Rhenish Wines, which was a certain management of them with Lead, by which they could give them an agreeable mellowness, but which enervated and destroy'd the drinkers of it with insuperable Palsies; for which reason it was justly branded with a most rigorous punishment.

In Brewing. *Isis*, and *Osiris*, instructed the countries that were destitute of Wine, by what methods they might prepare Beer from Corn, which was very properly therefore called the Wine of *Ceres*; and hence *Tacitus* tells us, that the ancient *Germans* used to make Wine from corrupted Corn. Now this the Art of Chemistry lays claim to in a particular manner, they both having their rise in the same part of the world, *viz. Egypt*. And indeed, *Basil Valentine* has elegantly given us the whole doctrine of the secrets of Alchemy, in his description of the Methods of making Beer, which he has examined with all possible nicety and accuracy. But there's no need to enlarge upon this head; for as there is very little difference between Wine and Beer, what has been said of the usefulness of the chemical Art in the former, your ingenuity will easily apply to the latter.

And thus, Gentlemen, I think I have sufficiently made appear the abundant services that all the mechanical Arts, or the chief of them at least, receive from Chemistry. And hence, I believe, I may safely conclude, that if the particular Artists in the different branches of Mechanics, had a good knowledge of the chemical Art likewise, they would be able to improve their several professions to very great advantage. There are therefore very many and weighty reasons, that urge us to apply the Art of Chemistry to all other Sciences that are engaged in the examining and changing of natural Bodies. And this we should do with a resolution, carefully and faithfully to take notice of every thing that we may be so happy to discover, which we should afterwards digest in order, and publish to the world; that thus, by the united labours of us all, human Arts may be improv'd, and carry'd to still greater and greater perfection. What I have been able to contribute to this valuable purpose, I have given you; I confess, indeed, it is but a little: In this view, however, the pains I have taken, will be of some advantage, if it serves to incite other persons of a happier genius, and greater application, to make more useful Discoveries.

In Alchemy. And now at last we are come to lay before you a few simple observations concerning the excellent usefulness of the chemical Art in Alchemy; where I shall candidly represent the affair exactly as I have found it. Among all the Writers of Natural Philosophy, it has not yet been my fortune to meet with any, that have more intimately examined, and evidently explain'd the nature of Bodies, and the effects they are capable of producing, than those that have
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gone by the name of Alchemists. For the confirmation of this, lest I should be unjustly suspected of prejudice, I beg you will read, but with a vast deal of attention, the works of the principal, true, professors of the alchemistical Art. Give me leave upon this head, to quote *Raymond Lully*, in that Treatise of his, which he calls *Experiments*. There you will see with what perspicuity he explains the nature and actions of Animals, Fossils, and Vegetables, and that purely from simple experiments, without any circumlocution, disguise, or fiction; and I am satisfied, you will candidly acknowledge, that you can scarcely find these things treated of in such a manner any where else. The observations, says that Author, that Bodies resolv'd by our Art, expose to the Eyes, and discover to the Mind, are of infinitely more force to gain the assent, than the utmost strength of pure Argument; by these we perform what we assert, and give Examples of what we inculcate. And it certainly must be allowed, that he did as he said: So that in reality, these men attempted to found such a Philosophy, as the great Lord *Verulam* so earnestly wish'd for; which should consist in the right comprehending and explaining to others those powers of Bodies, which being in action, would constantly produce certain determin'd effects; and hence should lay down no other causes of things, than what being at any time supposed, would certainly and readily effect those very things, thus always performing at pleasure whatever it asserted the truth of. They laugh'd at the subtle universal causes, which the Schoolmen, making an ill use of their leisure, imposed upon the learned world; for these were intirely the effect of pure speculation, and the knowledge of them did not at all qualify the possessor for any physical operations. And hence they most carefully inculcate throughout their Philosophy, that it is absolutely impossible for the utmost Art of man to produce any effects in natural Bodies, which shall exceed those powers that the divine Being has implanted in them: That some of these qualities lie open, and manifest to every one's observation, for the necessary uses of life; whilst others of them are more abstruse and conceal'd, and are only discover'd to those persons, who with diligence and constancy wisely apply themselves to search out the deeper and more hidden Works of the great Creator: But that both nevertheless are to be regarded as equally natural. They assert, therefore, that no person living, even supposing him to be possessed of all the wisdom of past and future ages, can ever, with all his skill, either create any one single Being, a grain of Mustard-seed, for instance, out of nothing, or produce it from any other kind of matter, that is of a different nature: But that prudent men, however, by receiving and examining created things, as they are offered to their observation, may, by the help of proper Experiments, come afterwards to discover by what law Nature acts, and what methods she pursues, in forming, producing, and perfecting every particular Being, according to its proper and peculiar Nature. And here they observe, that this is found to be the grand principal law, that every thing is generated from something of the same kind that first existed. Thus Plants spring from Plants; Animals from Animals; and Fossils from Fossils. They further assert, that the whole power of Generation consists in one seminal principle, which digests and changes the crude matter it receives into its own likeness, and forms it into a resemblance of the original: That in order, however, to a fruitful procreation, there is absolute-

ly required both a Male and Female, without whose natural conjunction, no Offspring can ever be produced: That when the prolific Seed is safely secured in the Matrix or Womb that nature has design'd for it, and has there for a convenient time been cherish'd, and supported with a kindly warmth, and proper nourishment, there will then appear a new Being resembling its father; whereas if Nature is any ways broke in upon, and disturb'd in her proceedings, her designs will prove abortive, and the thing that was intended will not be accomplished. Hence they infer, that after creation is once perfectly compleated, there is nothing begotten *de novo*; but that all things spring and increase according to certain laws, purely from the Seeds of something of the same nature that was in being before; that any created thing therefore, by means of its Seed, may be multiplied *in infinitum*, but not without it; and consequently, that the whole face of the Earth might be covered with one sort of Plant, as Fennel, for instance, if its Seed was continually gathered, sown, and cultivated, as its particular nature requires. They remark yet again, that there are found in Nature some Bodies, and those generally exceeding simple ones, that are not observ'd to have any seminal power in them; and hence, neither increase themselves, or transmute any other Bodies into their Nature, but serve, either to put every thing in motion, as Fire; to dilute, and be a proper vehicle for nourishment, as Water; or to give strength and stability to compound Bodies, as Earth, when it is perfectly pure. Now these things being found by an infinite number of Experiments to hold good in all other parts of Nature, they at last discover'd, that even Fossils were subject to the same universal law. For tho' their natural simplicity, and the similarity of their parts are inconsistent with the organical, compound, fabric of a Seed; yet they are found to be indued with a certain innate faculty, by which they can attract a proper *Pabulum* for their increase, and apply it in such a manner, as to be hence continually propagated. They add farther, that the Spirits called *Reſtores* are sealed up, and do not appear in Metals so long as they are dead; but that when they are resolv'd, open'd, and vivified, they then manifest themselves, and produce very sudden and wonderful effects; and that even here there is a kind of prolific union; for they tell us, there is an impregnating Male, and a fruitful Female, by whose procreating power live Metals do propagate their Species. Nor have they conceal'd from us, by what methods Metals may be made alive, with what degree of Fire they must be managed, in what proportion they must be mix'd, and with what *Pabulum* they must be nourished, in order to make them capable of being multiply'd as long as you please. And lastly, they assure us, that Metals alone, on account of the extraordinary simplicity of their Nature, may be produc'd in the least time imaginable from a mercurial heavy fluid, fix'd by a sulphureous seminal principal, if they can but be intimately mixt by the assistance of Fire, and join'd together with an indissoluble union: That thus Mercury is the Mother of Metals, and the quickening Sun the Father: And hence, that that may be effected upon Metals in the twinkling of an Eye, if they are first artfully and properly vivified, which would not have been brought about by a subterraneous Fire in the Bowels of the Earth under a long *Series* of years. They confess'd, indeed, that in the Vegetable, and Animal Kingdoms, the action of procreation is limited, and determined by nature within its proper time: And that it was impossible it should be otherwise, considering

considering the exceeding tender nature of the Seed, its compound, intricate, and curious structure, the very various, and numerous parts of which it is composed, and how easily the living spark in the center of the prolific Sulphur, or the little Embryo, might be destroy'd. But at the same time they tell us, that in the pure Metals, Gold, Silver, and their Mother, Mercury, there is such a similarity of parts, that every individual particle is perfectly of the same nature with the whole Mass: That they are observed to be so greatly immutable, that neither the gentlest or strongest Fire is capable of destroying them: That the prolific seminal power resides in Fire, and hence acts with infinite celerity, and in a moment assimilates the mercurial matter that is suitable to it: That upon this principle depends the increase and procreation of pure Metals: And that thus may be prepared the *Philosopher's Stone*, which will convert all other Metals into Gold; on which head, if you desire to know my opinion, I'll give it you freely.

The wise *Socrates* having a Book of *Heracitus's* given him to peruse, that was wrote in a very intricate and abstruse manner, he read it over with a great deal of care, and when his opinion was desir'd concerning it, the great man answer'd, that in those places where he understood it, he found it excellently well done, and believed it was the same, where he was not able to comprehend it; but that it required the most subtle penetration to come at the sense of it. In the same manner, where I can discover the meaning of the Alchemists, the truths they deliver appear very evident, and are express'd in the most simple terms, nor are they often mistaken themselves, or do they impose upon others. When I come therefore to passages where the sense is more obscure, why should I pretend to condemn them of being in the wrong, who have shewn themselves vastly my superiours in the Art, and from whom I have got a great deal of information, where they thought it proper to express themselves clearly? For they themselves declare, that when they come to treat of the utmost limits and perfection of the Art, they designedly tell us no more than that the Art is true, in order to excite proper persons to pursue and discover it: That they are obliged in honour, not to publish a secret that might be abused to a great many ill purposes: And that it is enough, if they point out to us the tract that Nature teaches us to follow, and prevent our falling into errors. For this reason therefore, I am rather apt, in these circumstances, to lay the fault on my own ignorance, than to accuse them of vanity. With proper deference, however, I must take the liberty to make the following remark: When I read over the Secrets of those excellent Artists and great Masters of Nature, I am apt to doubt, whether, after they had by pure observation made so many, and such singular discoveries, they did not arrive to such a quickness in perceiving the consequences of things, as led them to relate those things for facts, which they judg'd might possibly be, nay, and certainly would happen, if they had prosecuted the inquiries they had in their view. And indeed, *Alexander Suchtenius*, a considerable Author in Alchemy, who was a scholar of *Paracelsus*, and a zealous defender of his Doctrine, seems to intimate something of this nature; for after having try'd a great many things to no purpose, he tells us, in the end of one of his Treatises of Antimony, that all the Philosophers, of which he there mentions the chief, died before they had brought their speculations to a proper issue. Now supposing this to be

true, which I don't pretend to determine, yet every grateful mind will think itself vastly obliged to them for discovering to us those physical truths, which it cost them an infinite deal of pains to come at the knowledge of. And the great Lord *Verulam* very properly compares them to a Father, who when he was dying, made his lazy Sons believe, that in a certain field he had hid a treasure; upon which, as soon as ever he was dead, they went to digging, in hopes of finding the riches, but were baulk'd in their expectations, tho' the service they did the Land abundantly recompenc'd their trouble. These few things concerning the knowledge of the true Alchemists in Natural Philosophy, I have long desired to make known, that they may not be misrepresented, and condemn'd by persons, who are no ways capable of forming a proper judgment of their abilities. The chief performances the Alchemists pretend to are, as follow:

The preparing the *Philosopher's Stone*; a small portion of which being thrown into Metals, whilst they are in fusion, will in a moment transmute the true mercurial part into *obryzum* Gold, purer and finer than was ever dug out of the Mines, or procur'd by any docimastic Art; and at the same time will instantly consume and dissipate every thing contain'd in the Metals, that is not of a metallic mercurial Nature. This, they say, is of the same weight with Gold, brittle like Glass, of a very deep red Colour, and runs in the Fire like Wax.

The making another Stone of the like Nature, call'd the *Lapis Argentificus*, which will in the same manner turn all Metals, except Gold and Silver, into the most perfect Silver.

The carrying the *Philosopher's Stone* to such a degree of perfection, that being cast into melted Gold, it will totally convert the Gold into the *Philosopher's Stone*.

And the exalting this still higher, so as to change pure Mercury intirely into the same Stone.

They say farther, that they have discover'd a Body prepared by Art, which is of such vast efficacy, that if it is mix'd and united with any thing, either in the Animal, Vegetable, or Fossil Kingdom, it will so far improve their natural inherent vertue, as to render them the most perfect in their kind. In the human Body, therefore, it would prove a universal Medicine, so disposing both its Solids and Fluids, that it would become absolutely sound, and would continue so, till it was gently consumed and worn away by the necessary actions of life itself, and then would leave the world easily, and without reluctance. The same thing too it would effect in any living Animal; and if it should insinuate itself into the roots of Vegetables, it would greatly increase both their beauty and fruitfulness. To this noble figment they gave the name of the *Universal Ferment*.

They pretend likewise, to make artificial Gems, that shall perfectly resemble, and be of the same value with natural ones.

And to exalt the baser imperfect Metals into Gold, by carrying on their coction and purification from that step, where Nature was defective and left off. For it is their opinion, that the ultimate design of all Nature's operations in the Mines, is the production of Gold from Mercury by the assistance of Fire, and by refining and filtering it through pure dense Bodies: That if she is hindered in her proceeding, either by the want of Fire, the looseness of the passages through

through which it runs, or the mixture of any heterogeneous matter with it, there then arises a crude Metal which is not perfectly homogeneous, and hence mutable by the Fire. And thus they say are produced all Metals except Gold, Silver, and Mercury; which, nevertheless, may be still so far perfected by Art, as to be converted into Silver and Gold. This last, however, was not the universal opinion of the Alchemists. And indeed, Lead, Tin, Copper, and Iron, seem as perfect in their kind, as Gold; and are always found to be precisely of the same determinate nature. And, perhaps, the particular nature of Copper may render it as fit, or fitter, both for philosophical purposes, and the common uses of life, than either Silver, or Gold, although it is less simple, and consequently more changeable. Nor in reality is it at all probable, that this Metal should, by any continued subterraneous digestion and separation of its heterogeneous parts, be ever exalted into Gold, or become any thing but the most perfect Copper; which is likewise true of all the rest. I confess indeed, that something of Gold may be obtained from what we call the baser Metals, if they are kept a long time in the Fire; but then it is not certain, whether this is actually produced there by carrying on those Metals to greater perfection; or whether it is only separated from them by the force of the Fire. Nor can I easily conceive how it comes to pass, that lead, which of all solid Bodies, comes nearest in weight to Gold, should be reckoned so much more distant from it in nature than Silver; since all the Adepts assert with one consent, that the Demonstration from weight is of more force than any mathematical one. But I have sufficiently tired both your patience, and my own, upon this subject, and therefore to conclude. Let us never imagine that we are able to determine how far the powers of nature may extend. Those things are looked upon as impossible, that ignorant people are not acquainted with. The ancientest Philosophers gave some hints of an eternal Fire, solid, and durable even under Water; and were ridicul'd for their pains as a parcel of idle men: But since it has been discovered by *Craftius*, improved by *Kunkel*, described by *Boyle*, more clearly explained by *Newentyt*, and most plainly of all treated of by *Hoffman*, the possibility of the thing is actually demonstrated. The artificial Thunder and Lightning of *Roger Bacon* were looked upon for a good while as fiction, and deceit; but they afterwards were made appear by *Schwartz* to have too much truth in them. And the other things that I have mentioned in natural Magic, to persons perfectly unacquainted with Experiments, will seem much more incredible than the transmutation of Lead into Gold with regard to its mercurial part, its original form being first perfectly destroyed. There are inconveniences in being too credulous; and so there are in being too sceptical. It is the business of a wise man to try every thing, and abide by that which he finds to be true; nor ever to prescribe limits to the power of the omnipotent Governour of the universe, or the natural beings which he has created.

Now we are upon this head give me leave, before we proceed, just to mention the *Apparatus*, that the greatest Masters in the Art declare to be absolutely necessary for bringing this grand *Arcanum* to perfection. And first they all agree, that Gold, Mercury, and Fire, are principally requisite. As also Lead, Iron, Antimony, and Nitre, and the nitrous spirits drawn from it. A Cupel. A glass Pestil and Mortar. A Retort, Receiver, and pure Water. A Furnace,

nace, Bellows, filtering Papers, a glass Egg, or Matras, and an Athanor. The whole charge of which upon computation never amounts to 20 l. Sterling, setting aside the value of the labour.

Of the Instruments of Chemistry.

Having thus, Gentlemen, explained to you the Bodies about which Chemistry is engaged, and the ends that it chiefly proposes in the changes it produces in them, I suppose of course you will be desirous to be informed by what methods these may be brought about; which I readily comply with. As it is impossible now that any Art can produce effects without proper instruments; hence these, of consequence, come first under our consideration. A person, for instance, desires that I would acquaint him, what it is in Wormwood that gives it its bitter taste, and that I would separate that part from all the rest. Now here I must know that Water just ready to boil will fetch all that is bitter out of the plant, if it is poured on, digested, decanted again when it is impregnated, and this is repeated so long till the last after standing some time comes off as insipid as it was put on. The Plant then will intirely have lost its bitterness, which will all be contained in the Water: And here you see evidently, that Fire, and Water, are the Instruments made use of in this Operation.

For in every Art that instructs us in the changing of Bodies, that particular thing is called an Instrument, which either has or may have given it a certain peculiar motion, which being applied to the Body to be changed will produce such an alteration in it, as the Art had before determined. And thus in Chemistry we have Instruments by which we are able to perform the actions we desire; and these we usually reduce to fix, as the principal, with those Chemists who have cultivated the Art with the greatest accuracy; and they are as follow. Fire, Water, Air, Earth, the Solvents which the Artists call *Menstruums*, and the common furniture of the Elaboratory; all which the Chemist ought well to be acquainted with, if he would rightly understand the Operations, which are effected by the help of them. Of these therefore I shall treat in the order I have mentioned them, beginning first with Fire, as there never was, or can be any chemical Operation, in which Fire is not concerned; which is not so universally true of the rest.

Of FIRE.

The power of this is so great, its effects so extensive, and the manner of its acting so wonderful, that some of the wisest nations of old revered and worshipped it, as the supreme Deity. Some of the Chemists too, after they had discovered its surprizing vertue, have suspected it to be an uncreated Being. And indeed, the most famous of them have acknowledged it as the source of all their knowledge; and hence have professed themselves Philosophers by Fire, nor thought they could be honoured with a nobler title. Now among all the wonderful properties of Fire, there is none more extraordinary than this, that though it is the principal cause of almost all the sensible effects that continually fall under our observation, yet it is itself of so infinitely a subtil nature, that it eludes the most sagacious inquiries, nor ever comes within the reach of our senses: and hence others have been led to be of opinion that it ought to be looked upon as spirit, rather than Body. It

Fire of a
wonderful
nature.

It is necessary, therefore, if we would keep clear of mistakes, to act with the utmost caution in our searches after a thing whose nature is so hidden and mysterious. And for this reason we must absolutely disengage our selves from all mere speculations, nor give into any precarious *hypothesis*, how plausibly soever contrived, unless we would run headlong into confusion, and uncertainties: For if at setting out we lay a wrong foundation, the errors that arise hence will diffuse themselves through all the branches of natural Philosophy; since in all the productions of natural effects, Fire, as I observed before, has always far the greatest share.

To be in-
quired after
with cau-
tion.

When we set about therefore to inquire what Fire really is, we must begin perfectly as though we knew nothing of the matter, and must intirely lay aside every notion that we had formed of it before. And here we must follow the analytic method of the Geometricians, who in order to come at the knowledge of any thing, proceed as though they were ignorant of it, and that they may constantly keep this in their eye, represent it always by some sign that only expresses something unknown, and that is then sought after. Nor do these religious Observers of truth, in their inquiries after things they are not acquainted with, ever make use of any other properties, than what are evidently observed in the things themselves, or have been before clearly demonstrated.

Not from
Hypothesis.

And I will venture to assert, that this extraordinary circumspection is never more necessary, than in the subject we are at present engaged in: For the Elements of Fire pervade and reside in the most solid matter of Gold, as well as in the most perfect *Torricellian vacuum*, and are equally dispersed and distributed through all Bodies, and every part of space; as will be evidently made appear hereafter. And hence it comes to pass, that there is nothing in our philosophical Inquiries more difficult, than truly to distinguish the particular action of Fire from that of the other causes that in every physical Operation concur with it; and yet the nature of Fire is so vastly different from theirs, that they cannot be confounded with one another without the utmost impropriety, and danger of mistakes.

One difficul-
ty in this
Inquiry.

There is yet another difficulty that puzzles the Philosophers in their searches after Fire as much as the former, and that is, the vast subtlety of its particles, which in their fineness not only exceed every thing yet known, but penetrate into the most solid, and even the smallest Corpuscles that ever fall under our notice. And hence it comes to pass that we find such very different, and absurd opinions concerning its nature, even among those Authors, who have studied it with the greatest diligence, and happiest success. And the errors that have risen hence, have not only infected Chemistry and Philosophy, but have also spread themselves into the medicinal Art; as every Physician must acknowledge, who has carefully considered what has been advanced concerning innate Heat, radical Moisture, and many other things that depend upon them. Let us therefore in our Inquiries on this subject proceed as if we were perfectly unacquainted with it; and let this be the case, 'till we are able to come at some certainty about it.

A second.

It is impossible, however, with our utmost endeavours, so to disengage our thoughts in this affair, as not to retain at least that idea of Fire, by which every person says he knows whether it is present in any particular place, or is absent.

The signs
of its pre-
sence to be
first investi-
gated.

absent from it. For it is absolutely necessary that this mark should be perfectly obvious to our senses, and that we should all agree about it; otherwise the word Fire even among persons that talk the same language, would signify nothing at all. And the same Observation equally holds true of every thing else. If a person should say, for instance, that he knows nothing of the nature of Thunder; yet still under this word he conceives this notion of it at least in his mind, that it is something that produces a very extraordinary noise in the Air, and thus understands the same thing by this term as every body else does, nor will easily confound it with any thing else. In like manner, both the learned and the ignorant, if they use the same speech, as soon as ever they hear the word Fire, immediately think of the very same thing. And indeed were not this the case, that word would have no more effect upon the person that heard it, than if it had been spoken to an *Indian*, or an *African*.

The requisites in these signs.

Now this general mark or character must belong so peculiarly to Fire, that it must not be common to any thing else; for otherwise, we shall be constantly at a loss how to distinguish Fire from any other of those things, that this property might equally point out.

Nor is it less necessary that this mark should be an individual one, and absolutely inseparable from Fire, so that wherever Fire actually exists, this should also most certainly and constantly be present with it; for by this means alone we shall be able to come at the knowledge of it, a sign being of no manner of service, if the thing signify'd may nevertheless lie concealed, and not be discovered by it.

And lastly, it is absolutely requisite, that this character should lie open to our senses, and easily affect them; and should plainly point out to us the degrees in which Fire increases, decreases, or continues in any space, or Body. If these three properties, therefore, are found together in any character of Fire, we may venture to make use of this for our purpose.

The use of such a sign.

And then safely relying upon this, we may cautiously proceed to some physical Experiments in order to get a farther insight into the nature of Fire, which though indeed it lies out of the reach of our senses yet, by this sign will certainly discover its being present: Especially, if we set about our Inquiries with prudence and diligence, on purpose to examine into its hidden properties, when we are once undoubtedly sure of its presence. And, then besides, any accidental discoveries that unexpectedly offer themselves to our observation in the prosecution of these Inquiries, will likewise prove of service: For both these will serve to furnish us with arguments, which being properly reduced into order, and rightly improved, will help us by degrees to an insight into the nature of this abstruse, and mysterious Being. And how can we be afraid of falling into mistakes, whilst we pursue this method, which is universally approved by men of the soundest judgment, as the only certain one in searching after natural knowledge?

The difficulty of finding such a sign.

It must be acknowledged, however, that it is exceeding difficult to discover such a mark of Fire as will always demonstrate its presence, let the quantity of it be ever so small; and that for the following reason. Upon examination it evidently appears that there is an incredible quantity of true Fire even in those places, where every body not only judges there is none, but imagines there is really something of a quite different nature. In a hard frost, for instance, it will be demonstrated,

demonstrated, that Fire is actually contained in the very coldest masses of Ice, and may be instantly produced from them with a great deal of violence: And yet at that time it no ways manifests itself to our senses; not one of its actions appears; nor any of the effects that are commonly ascribed to it. I don't pretend, therefore, to lay down any mark, by which a person may be sure of the presence of the very least quantity of Fire; but I'll venture to offer one which will certainly discover it when it is somewhat greater; which will be sufficient for our purpose. And as in Bodies, we have no idea of great, or small, except by comparing the Bodies, either with one another, or with some certain measure: So here, though the absolute quantity of Fire in a given place, cannot by any sign be rightly determined; yet we are able to demonstrate how much there is more, or less of it there, than in any other place assigned. In like manner it is difficult to ascertain the absolute degree of Fire in any particular point of time; and yet the various degrees of it at different times may be easily compared with one another.

Whilst we are engaged now in pursuit of the marks abovementioned, those effects first offer themselves to our observation, which are produced by the power of Fire alone, and by which, when they are manifest to our senses, we universally infer the presence of Fire. These therefore we may fairly make use of for the present. For if those physical changes which are the sole production of Fire very easily affect our senses, they will serve as a certain indication of Fire; and if these constantly appear wherever Fire is generated, we shall come, in reality, at the very thing we desire. Nor need we here be over solicitous lest among these effects there should be sometimes intermixed others, that owe their being to some other causes; for when we come to consider them more nicely, we shall easily be able to distinguish those that are proper to Fire, from those that are common to it with other Bodies. Let us therefore at first assume those properties only that are commonly, and universally ascribed to Fire; and afterwards proceed to examine them with care, and accuracy, in order to make a proper discovery of those among them, that we are particularly in search after. Now of these the following are the principal. 1. Heat. 2. Light. 3. Colour. 4. Expansion or Rarefaction, both of Fluids, and Solids. 5. The power of burning, melting, &c.

Such signs
are the sen-
sible effects
produced by
Fire.

These therefore let us consider in order. Heat then in the first place is ascribed to Fire, and that with the greatest reason, as they are most intimately connected together. And yet if we closely contemplate this very idea of Heat, we shall easily perceive that people mean nothing more by it, than a certain sensation of the mind, excited by the application of Fire to the sensible parts of the Body. But by this perception certainly we understand nothing of the action of Fire, or the alteration that is produced in our organs of sensation by it. And hence Heat, considered only as it exists in the mind, whence alone it receives its name, does not really signify any thing corporeal, but indicates only some affection, or change of our thinking faculty. When any person is hot, he has a clear and distinct idea of what he feels at that time; but yet he will never thence be able to obtain the least knowledge of Fire, or the changes that it then produces in him. Let me ask you, Gentlemen, what it is you feel in yourselves, when you say you are warm; is it not a perception of somewhat agreeable? Now compare this with what the Physicians are of opinion

The ex-
amination
of these,
and first of
Heat.

happens then in the Body; and what a prodigious difference! They tell us that during that time a most subtil Fluid is moved in the capillary Nerves after a particular manner: But is it possible that ever such a notion as this should enter into any person's mind purely from the sensation of warmth, should he be affected with it ever so often? But consider again, what is the standard by which every one measures his proper degree of Heat? Why, so long as a man enjoys perfect health both in body and mind, he will confess that the kindly warmth he then feels, excites an agreeable sensation in his mind. If this afterwards lessens by degrees, and at last becomes imperceptible, he then says he is cold: As on the contrary, if it is increased beyond that degree which affected him with pleasure, he complains of a troublesome Heat. But there is nothing in all this that will be of any service to us, as a Criterion of Fire. Besides, as in all other circumstances, so here, the degree of Heat that we are constantly accustomed to, we are not sensible of; and hence we are apt to look upon every degree of it, that is less than the natural, or usual one, as no Heat at all; which leads us continually too into mistakes: Whereas on the contrary, those persons that have for a long time been inured to cold, are thence affected in a very different manner from what others are. It is an old Observation that subterraneous places afford a most refreshing coolness to persons melting with Heat in the sultry Dog-days; and that on the other hand, when the Body is almost frozen with the winter Cold, it will perceive a kindly warmth in the very same places. And hence it has been falsely inferred, that these places under ground undergo a true *Antiperistasis*, and grow colder in Summer, and warmer in the Winter; whereas we certainly know that cellars considerably deep are colder in the former, and warmer in the latter: Indeed if they are sunk to a very extraordinary depth, the degree of Heat continues always pretty nearly the same. From all this we conclude then, that the informations we receive from Heat are very precarious and uncertain. For your farther satisfaction, however, I will mention one instance more, of great consequence too in Physic, which will still farther confirm my assertion, that we can by no means determine with any certainty the quantity of Fire, by that Heat with which our senses are affected. In the summer time, when the Heat grows excessive, suffocating, and intolerable to persons in health, occasioned either by the reflexion, or refraction of the Sun from the Clouds, there follows very frequently Thunder and Lightning, with large showers of Rain, and sometimes of Hail; and this no sooner happens, but the Air grows chill, and this very troublesome Heat is succeeded by Cold. With this sudden change we are ready to shudder, and feel as though we were pierced through with a Winter's Frost; and yet I have found by repeated Observation, that the Air at that very time, though it seems so cold, is in reality so very warm, that should the same come upon us suddenly after a very hard frost, the Heat of it would be greater than we could possibly support ourselves under: For should a room, in the sharpest frosty weather, be heated to the same-degree, as the Atmosphere is in the month of *August* after such Thunder, there is no person living who had been abroad a good while in this piercing Cold, that could bear the Heat of this room, but would soon faint away. From the whole therefore we conclude, that Heat is a very uncertain measure of the quantity of Fire.

Secondly of
Light,

Again, Light is looked upon by judicious Men as a most certain Demonstration

stration of the presence of Fire. For, say they, does not this offspring of Fire evidently point out its parent, and hence imagine, that the stronger, and brighter its rays are, the greater quantity of Fire is really contained in it; and that on the contrary this decreases in the same proportion, as the splendour of that noble Being is diminished. This therefore they imagine may be laid down as a mark of Fire. But how little, Gentlemen, are they acquainted with experimental knowledge that are of this opinion? If you make any doubt of this, put a piece of Iron in the Fire, and let it remain there 'till it's almost red hot, then carry it into the dark, and it will afford no light at all; and yet if you apply it to the body of an animal, it will burn it to the bone, nay the very bones themselves, with a hissing noise, and a very disagreeable smell; or if you lay it upon a piece of dry wood, you will produce both sparks and flame. Here, therefore, there is a vast deal of Fire without the least appearance of Light. On the other hand, take a concave *Speculum* made of solid Metal, and exactly polished, and in a clear winter night oppose it to the Moon when it is at the full and upon the Meridian, then place a piece of white paper in the *Focus*, so that it may receive the contracted image of the Moon, and you will have so refulgent a Light, that the strongest eyes will not be able to bear it; and yet in the center of the *Focus* there will be a very piercing Cold. The same Experiment was performed by that famous *English* Philosopher Dr. *Robert Hook*, (who seemed formed by nature for Experimental Philosophy) with a double Convex-glass, and the image of the Moon received upon a paper in the *Focus* was excessive bright; and yet upon putting a very nice Thermometer into the *Focus* there did not appear the least sign of Heat, or Fire. The same thing was afterwards confirmed by *Tschirnhausen's* glasses at *Paris. Mem. de l'Ac. Roy. des Sc.* 1699. p. 110. And lastly, in the *Focus* of *Vilett's* Mirrour directed to the Sun at mid-day, there is not the least appearance of a lucid image, unless it falls upon an opaque Body, or a person should on a sudden fatally put himself directly against it; and yet there is in that very place a Fire so intensely hot, that it is able in the least instant of time to melt even stones themselves. Now will any one pretend that Light can be a proper measure of the quantity of Fire, when we evidently see, that there may be the strongest Fire without any visible Light; and on the other hand, the most refulgent Light without producing the least degree of Heat?

Upon the head of Colour now, there is little room to say any thing: For as this is either Light itself, or a various reflexion of Light from opaque Bodies, it is evident from what has been demonstrated of Light's being an insufficient mark of Fire, that Colours of consequence must be much less so. And Colours

As these, therefore, do not answer our purpose, we must carefully examine the remaining effects of Fire, to see if we cannot at last discover one of them, which will serve us as a certain token, and a proper measure of the presence, and quantity, of this most active Element. But alas, Gentlemen! the more accurately one contemplates them, the readier one is almost to despair of gaining one's point, they appear so full of contrarieties. If we consider, for instance, its power of attenuating Bodies, why we see, on the other hand, that a great many are more closely compacted together by it. Some are consolidated by this Element, whilst it has a power of dissolving others. Many it separates into different parts, though at the same time it unites, and combines others more And the other effects of Fire.

intimately, than can be effected by any thing else; as we see plainly in the making of Glafs, and the mixing of Iron and Gold. But this fruitful argument will carry me to too great a length: In short, therefore, I'll venture to assert, that you can scarce mention any one effect of Fire, which you may imagine to hold good in all Bodies, but I'll shew you a quite contrary one produced in some, by the very same Fire. You'll be apt therefore to say, does then this wonderful cause produce no one effect, which is always, and every where the same, perfectly inseparable from it, and constantly invariable in every kind of Object? Why, Gentlemen, I believe there is such a one; and by the most faithful, and diligent inquiries I have been able to make, I never could discover any more.

The rarefaction of Bodies a mark of Fire.

For upon a careful examination of natural Bodies, I don't find any one to which that Being may not be applied, which we generally call common Fire, whether solar, artificial, or subterraneous: But ever body, without exception, that has been hitherto try'd, upon its being united with this Fire, increases in its magnitude, swells, and rarefies, without any apparent alteration in its weight. Nor does it at all signify whether they are solid, or fluid; hard, or soft; light, or heavy; for the same law holds constantly and universally true in all.

If you take two Bodies, however, of the same bulk and weight, one of which is solid, the other fluid, you will always observe this difference, that the fluid one will suffer a greater expansion from the same Fire, the solid one a less: At least, I have never found it otherwise in those that I have hitherto made trial of. Fluids, therefore, are more proper for the examination of Fire by this effect, than Solids. But again, I have constantly found, that those Liquors which are less dense, and light, are always the most rarefied by the same degree of Heat; and consequently, the expansion of the lighter Fluids will most sensibly affect us, and are therefore the most suitable to indicate to us the very minutest augmentations of the smallest Fire. The truth of this I confirm by the following Experiment: You perceive, that this Glafs in my Hand, which consists of a spherical Body, and a narrow cylindrical Neck, is fill'd with fair Water as high as this mark which you observe on the Neck; as soon now as I dip the bulb of the Glafs into the warm Water that is contain'd in this open vessel, you see immediately that the Water in the Neck rises above the first mark, and ascends continually, so long as it acquires a still greater and greater degree of Heat. Again, if I take it out of this Water, and put it into that other which is somewhat hotter, you perceive that it rises still higher in the Neck of the Vial. And lastly, as I move it nearer and nearer to the Fire, you discern that it is more and more expanded; and that it descends again by degrees, as soon as ever I remove it farther from it. Now does it not hence very plainly appear, that the Water is expanded by the Fire, so as to take up a greater space when it is heated, than it did when it was cold, and that, without any sensible increase of its weight? And is it not as evident, that this solid glafs Vessel is not equally dilated with the Water; since, tho' this is heated to the same degree, and indeed sooner than the Water, yet the Bulb is not now able to contain it as it did before, and therefore some of it rises into the Neck? Again, please to turn your Eyes this way, and here you'll see how much quicker Alcohol of Wine rises in this Glafs, when it is immersed

immersed in the same hot Water, and how swiftly it mounts to the very top of the Neck, so that it is ready to run out at the Mouth. Hence then, with me you will readily infer, that Alcohol, which is lighter than Water, is sooner, and more rarefied by the same degree of Heat. These Experiments therefore, tho' they may seem plain and trifling, evidently confirm the truth of what I asserted. And I wish that those Gentlemen who have had a thorough knowledge of Hydrostatics, had given us the comparative weights of all the Fluids we are hitherto acquainted with: Then, possibly, I might have been able to lay down this as a general Rule, which the consideration of many of them suggests, *viz.* that the spaces of expansion from the same degree of Fire, are to one another, as the rarities of the expanded Bodies, or in a reciprocal proportion of their densities. These that follow are found, by Experiment, to succeed one another nearly in the order they are mentioned:

The lightest of all Fluids is the *Vacuum* of *Torricellius*.

Then *Boyle's*.

Air.

Alcohol.

Pure distill'd *Petroleum*, *Boyl. Mech. Qual.* 88.

Spirit of Turpentine.

Water.

Vinegar.

Aqua Fortis.

Spirit of Nitre.

Oil of Vitriol.

Mercury.

See the great *Boyle*, in his *Medicin. Hydrost.*

If seems, therefore, as if the easy expansion of the lightest Fluids, might serve as a certain mark of the presence, increase, or decrease of Fire: For this no ways depending upon our senses, which we find in these inquiries to be so uncertain a guide, will not easily lead us into mistakes. Besides, this will determine to the greatest exactness its very smallest increments, or decrements, which cannot be so nicely adjusted by any other method that I am acquainted with. And there is yet this further advantage in it, that it may most expeditiously be called into use in any place whatever that you have a mind to, even in the inside of Bodies, as well as without them; for it is always and every where equally ready for service. And lastly, it has this excellency in it, that this expansion of Bodies by Fire, if it is effected in a Glass hermetically sealed, cannot be produc'd by any other physical cause hitherto known. We have now therefore at length discover'd that property of Fire which we were in search after; which may, and ought to be regarded as a true, certain, individual, and proper mark of Fire. This then alone is what we shall make use of as we proceed in the investigation of its Nature; and we shall take it for granted, that in every *Phænomenon* where we see this rarefaction excited, there is there a proportionable degree of Fire as the cause of it; by which means we shall have an opportunity of examining it in almost every circumstance, and hence may fairly reason about its hidden Nature, which will discover itself to us in every Experiment of this kind. Now in the prosecution of these inquiries, we shall begin with the most plain Experiments, and proceed in order to those

those that are more uncommon ; and thus lead you by degrees from the simpler, to the more abstruse properties of this Element.

EXPERIMENT I.

Iron is in-
larg'd by
Heat in all its
dimensions.

Fire expands the hardest Bodies in all their dimensions so long as it is contained in them.

Which I thus demonstrate. You see these two iron cylindrical Rods, which are exactly three feet long, and pretty nearly of the same thickness, as you perceive by their just passing through this iron Ring.

One of these I'll put into the tower of this Athanor, in which there is a Fire ; and when it has been there a sufficient time to heat it, I'll take it out again. You see now that it is almost red hot, and that when I apply it to the other Rod that is cold, it exceeds it in length very considerably since it was put into the Fire.

Decreases a-
gain as it
grows cool.

You observe farther, very evidently, that as it cools, it grows every moment shorter and shorter : And now it is quite cold, it is of the same length with the other ; its length decreasing in proportion as the cold returns, and the Fire leaves it.

I have now again made the end of the same Rod red hot, and endeavour, as you see, to thrust it through this Ring, but am not able : For you are witnesses, that it is a good deal thicker now than it was when it was cold. But have a little patience till it is quite cold again ; and now you see it will go through the Ring : So that tho' this would not admit it when it was hot, yet it lets it easily pass through now it is cold.

A method
by which
this increase
may be mea-
sured.
Pl. I. Fig. 2.

If any person now has a mind to measure exactly the difference there is between the length of a piece of Iron, or any other solid Body, when it comes red out of the Fire, and when it is cool'd to any certain degree determined by the Thermometer, he may do it in the following manner : Let AB and CD be two parallel brass Plates, contriv'd so to move upon the side ones, that their parallelism may be always preserv'd ; and let the side ones be divided into very small equal parts. Take then the Body you design to make your Experiment upon, and fit it exactly, when it is cold, betwixt AB and CD, close to the Plate AC. Then put it in the Fire, and when it is red hot, as nimbly as possible place it pretty near the same AC, and remove AB from CD, till they can contain the heated Body betwixt them ; which must be done expeditiously, that AC may not be too much heated. You will then have the difference betwixt the Rod when it is cold, and after it is heated : But you must take care that the Rod be made sharp at both ends, as you see in the figure EF, that it may heat the Plates as little as may be. The same thing may likewise be determined in the manner following : Let AB represent a straight brass Ruler, the longer the better, at whose extremity B, let there be another pretty long one fixt perpendicularly, and minutely divided into equal parts, and let the brass Hypothenuse AD be made moveable at A, upon the plane ABC : Then if the heated Rod is placed upon AB, it will elevate the Ruler AD, and by the motion of this upon BC, you will have the difference you wanted, which will be the more remarkable, the longer you make AB, and BC.

Fig. 3.

This expan-
sion happens
in all Bodies.

I. Now this expansion of solid Bodies by Fire, is so universal, that I have never

never observed it to fail in any one that I have had as yet an opportunity of making trial of: Which is a remark of considerable consequence in our present inquiry.

Take care, however, you don't here fall into an error, by imagining this expansion to be equally great in all kinds of Bodies: For by every Experiment that I have hitherto made, it appears that heavier Bodies suffer a less, and lighter a greater dilatation from the same degree of Heat; so that this rule seems to hold true of all in general. But let it suffice that I have hinted these things to you; you yourselves will easily carry on these observations, by the help of the second instrument, and examine, whether, universally, the dilatations of solids by the same degree of Fire, are in a reciprocal proportion of their respective densities? I did design to have pursued this inquiry farther myself; but the multitude of my affairs, and the little time I had to spare, would not permit it: Those things, however, which I have seen and perform'd, persuade me to believe, that the rarer Solids are always more dilated, and the denser less, by the same Heat.

But is different in Bodies of different densities.

But there are still other causes that produce some variety in the degrees of this expansion of Bodies, besides the difference of their weights; which I came to the knowledge of in the following manner. I desired that industrious and incomparable Artist, *Daniel Gabriel Fabrenheit*, to make me a couple of Thermometers, one with the densest of all Fluids, Mercury, the other with the rarest, Alcohol, which should be so nicely adjusted, that the ascents of the included Liquor in the same degree of Heat, should be always exactly equal in both, as might appear by a scale fix'd on the side. This, after a good deal of intreaty, he endeavoured to do; but tho' he had made his calculations with the greatest accuracy, yet upon examination I found they did not perfectly agree. I acquainted this honest Gentleman, therefore, with my disappointment, and he candidly confess'd that there was a defect, and acknowledg'd frankly that he did not then know the occasion of it. However, not being satisfied himself, he set about more diligently to inquire into the cause of this difference; and upon a nicer examination he discover'd, that the various sorts of Glafs made in *Bohemia*, *England*, and *Holland*, were not expanded in the same manner by the same degree of Heat; but that one sort of it was affected sooner, and with more ease, another with more difficulty, and in a longer time. And hence he found out, that his method of making these instruments would succeed, if they were both form'd of the same sort of Glafs; but would be defective, if one was made of *Bohemian*, and the other of *Dutch*: For it appeared, that that Glafs which requires a stronger Fire to melt it will be less expanded, whilst that which runs easily in the Fire will be more dilated, if they are both exposed to the same degree of Heat. How infinitely careful therefore ought we to be in our searches after natural knowledge, if we would come at the truth? How frequently shall we fall into mistakes, if we are over hasty in laying down general rules? How vastly preferable is that Science, which is form'd with patience and deliberation upon cautious Experiments, to that which is the effect only of rash and precipitate ratiocination?

And varies too from other causes.

2. This expansion always increases in proportion, as a greater quantity of Fire is admitted into the expanded Body; so that this Rod, when it is perfectly white with Heat, is longer than it is when it is not red, tho' it should still continue exceeding hot; and it is shortest of all, when it has laid a good while

The greater the Heat is, the greater the Expansion.

while in the most intense cold. Here, therefore, I would again recommend to you, the making some Experiments upon Iron, (which of all Metals will bear the strongest Fire without being fused) in order to discover the difference of its length, when it is just upon melting, and when it is perfectly cold in the coldest season: For then you will have the action of this expansive power in its greatest latitude.

When Solids
are put in fu-
sion by Fire,
their expan-
sion ceases.

When once Iron is put in fusion, and becomes a fluid Mass, it seems afterwards to continue of the same bulk, tho' the action of the Fire upon it is increased by the assistance of Bellows: And then possibly, if it is not capable of receiving any more Fire, nor consequently, of being farther expanded by the force of any common one: For Metals, when they once are melted, do not seem, as far as one can judge, to admit any more Fire, except it is collected by Bellows, a Mirrour, or Burning-glass, and by this means directed to some particular part of them.

All the parts
of Bodies are
put in agita-
tion by Fire.

3. Hence we evidently perceive, that Fire, as it increases from the greatest degree of known Cold, to the most intense Heat, must necessarily dilate all the parts of the hardest Bodies to which it is applied, and remove them from their mutual contact. It appears farther too, that this extension, and the rarity of the Body consequent upon it, is successively augmented, 'till the whole Mass, supposing it fusible, becomes fluid in the Fire. And hence it follows, that all the constituent parts of Bodies, during the application of these different degrees of Heat, are continually expanded from the centre of their substance, as well as the whole Body itself.

Even in the
very hardest.

Thus then we see, that the particles of Fire which are distributed through the corporeal Mass, act with an equal force upon all its *moleculæ*, or corpuscles; nor is there any Body so hard, or rigid, that it will not submit to the power of this Element, and may be so chang'd through its whole substance by the very gentlest action of it, that there sha'n't any one part of it remain unaltered.

4. Now what is the expansion of Bodies, but a dilatation of them into larger spaces than they took up before? Hence therefore we infer, that their component parts must be constantly in motion during this extension. Nor does it less evidently appear, that Fire moves all the particles of the hardest Mass, both external and internal, towards every point of its surface, and always so much the more, the fiercer it is; till at last, having reduced them into a state of fluidity, it then violently agitates, mixes, and drives them one among another.

Does Fire
melt Bodies
into their
very Ele-
ments?

Does Fire then so attenuate and divide such a Body, that those corpuscles which are thus fluid, are in reality the very Elements of the Bodies, so long as they continue in this state? And is this the reason, that the particles of Metals, when in fusion, are so intimately mingled one among another, that it is impossible to reduce them to the same degree of fineness by any other method? Why certainly, the docimastic Art, which is the truest of all Arts, informs us, that if one grain of Gold is mix'd with a hundred thousand grains of the purest Silver whilst they are fused, so that they may be perfectly melted together, then the Gold will be so dispersed among the particles of Silver, that if you afterwards take the least bit of this compound, you will find the proportion of the Gold to the Silver, as 1, to 100,000: Nor indeed, has there ever been discover'd any limits to this division and distribution of the Gold among the Silver. If
you

you accurately examine, then, the effect of this Experiment, you must readily allow, that the Fire, whilst it gradually acted upon the Gold from its greatest degree of cold, so agitated its elementary Particles, that they continually cohered less and less, till at length their cohesion being perfectly destroy'd, they were separated, and run from one another. And here, Fire, so long as it exerts this force upon them, is the only cause that these Particles, tho' they touch one another, do not coalesce; for that being removed, they are again presently united into one solid Mass.

I confess, indeed, that the parts of pure Metals, when they are put in fusion, retain a tendency towards a union: For I always observe, that Gold, Silver, and other melted Metals, immediately collect themselves into a globular figure, perfectly in the same manner as Mercury would form itself into a sphere, if the weight of its parts did not prevent it. This property, however, cannot exert itself with any effect, so long as the violence of the Fire is continued; which is pretty extraordinary.

The parts of melted Metals attract one another.

Again, it is impossible to unite two pieces of Gold together in such a manner, that they shall regain the tenacity that's peculiar to this Metal, unless you first divide them into their ultimate parts, by reducing them to a fluid state by Fire; but then, as soon as ever they are cold, they immediately recover their former ductility; And what we have asserted of Metals, holds true likewise in other simple Bodies; as we see in fix'd Salts, Glafs, and many others. Lastly, it appears from what has been said, that it is not only possible, but really true in fact, that the most fix'd and solid Body, may be so continually agitated in its constituent Elements, that there sha'n't be any one Particle of the whole Mass, tho' ever so small, that will be absolutely at rest. All which observations follow so evidently, from the consideration of the aforementioned Experiment, that nothing can possibly be clearer. Does therefore the influence of Fire reach even to the most intimate nature of Bodies? Surprizing Power!

Fusion alone perfectly unites the parts of Metals when they are separated asunder.

5. Why therefore should that *Phænomenon*, which is often observ'd to happen, any longer appear so wonderful, viz. that houses built in the strongest manner, frequently tumble down in very hot clear weather, and for the most part in the middle of the day, when there is no wind at all to affect them?

6. From this property of Fire we learn yet farther, that Bodies removed into the torrid Zones, grow bigger in all their dimensions, than they were in a colder climate: That hence they will become comparatively lighter, as they contain the same quantity of matter under a larger surface: That their percussions, of consequence, will be more feeble: That *Galileo's* pendulums, therefore, that are made in the frigid Zones, if they are remov'd into the torrid ones, will increase in their length, of course, and will take up a longer time in performing their oscillations; on which account clocks the best carried thither, will be found to vary from the truth. The same things in proportion hold true likewise in the same climate, according to the various vicissitudes of Heat in the different seasons of the year.

The same Bodies not equally great in all parts of the world.

7. That very ancient observation therefore is most certainly just, that Bodies are principally relax'd and weaken'd by Fire: For as these two words denote that condition of the Solids by which they are disposed to have their parts more easily separated, it evidently appears from what has been said of

The laxity of Bodies, what.

N

Fire,

Fire, that this is the very thing it is effecting from the first instant of its acting upon them, and that through every degree of its increase it brings about this dissolution more and more, till at length the most solid parts retain their firmness no longer, but dissolve, and melt away. And this is confirmed by the universal testimony of all Historians, who inform us, that the inhabitants of *Asia*, and *Africa*, who are exposed to the scorching heat of the Sun, have always been of a softer and weaker make, and less fit for hard labour, than those of colder climates. And in like manner we see, that in the most ardent Fevers, our Bodies are quite dissolv'd, and enervated. I confess, indeed, that at that time too they are parch'd up with the heat, and by this means grow dry and more rigid: But then this is not to be attributed to the Fire, as it is dispersed among the Solids, but only as it dissipates the most watery part of the Fluids; and in this sense alone is it true, that Fire ever gives strength to Bodies when once they are debilitated.

EXPERIMENT II.

Cold reduces all Bodies into a less space,

Cold, by which we universally mean the absence of Fire, contracts the hardest Bodies in all their dimensions, so long as it remains in them. This I demonstrated to you so plainly in the latter part of the former Experiment, that it would be paying a very indifferent compliment to your understanding, should I attempt the proof of it again. You'll give me leave, however, to point out to you the consequences that evidently follow from it; of which let this be the first.

Of what kind soever.

1. All solid Bodies are equally affected by this action of Cold; nor was there ever observ'd any one, tho' ever so firm, and closely compacted, but might be still farther condensed by it; even Diamonds themselves, the hardest of all Bodies, not excepted.

This contraction increases in proportion to the cold. And lessens the cavities of Bodies.

2. This contraction of Bodies is always increased, in proportion as the cold is augmented; and the former expansion, which they had in a lesser degree of cold, is diminish'd; which ought to be consider'd.

And, which is pretty remarkable, this reduction of Bodies into smaller spaces, happens even in hollow spheres, and orbicular rings, and is directed towards the center of the Body, or Surface. For when this Iron ring is cold, it will not admit this Iron cylinder, tho' it will receive it within its cavity after it is heated. This glass sphere, with this very narrow cylindrical neck to it, is fill'd as you perceive with a colour'd Liquor, as high as this mark which you see on the Cylinder: I dip this now into a Fluid, that is a good deal colder than the Sphere, and what is the consequence? Why you observe, that the Liquor in an instant rises very discernibly higher than it was before, tho' afterwards, indeed, it sinks down again. And the reason of this is plain; for the external cold being immediately apply'd to the Surface of the immersed Sphere, must of course affect that, before it can reach to the included Fluid; and hence, that being contracted into a narrower space, must necessarily expel some of that Liquor into the neck, which before it was capable of containing: But afterwards, when the cold has intimately penetrated into the Liquor itself, that is condensed as well as the Glass, and so must of consequence descend again. From this Experiment then we learn very clearly, that this power of contraction exerts itself, if I may so express myself, upon the very substance of

of Bodies. In other glass vessels made hot, and then exposed to the cold, this coarctation is much more evident.

3. Again, it appears, that this contraction of Bodies into lesser spaces, proceeds always in proportion to the cold itself; whence it plainly follows, that since they still contain the same quantity of matter in a lesser bulk, it must increase their comparative, or specific gravity: Nor is it less evident, that every Solid is then actually least, when it is affected by the intensest cold. As there is, however, no assignable Body in which there is absolute Cold, or no degree of Fire, hence, it is impossible to reduce any Body, an ounce of Gold for instance, to its least possible size; tho' the proportion of this condensation from different degrees of cold may be nevertheless discover'd.

Hence the specific gravity of Bodies uncertain.

4. From the sole absence of Fire, therefore, there raises in every solid corporeal Mass a very surprizing motion, both in its internal and external parts, by which all its Elements constantly tend towards its center, and by this means become more intimately united with one another. If then we consider cold as a mere privation of Fire, it follows, that this power, by which the Elements of Solids contract themselves into a smaller space, must be look'd upon as something implanted in matter itself, whilst the force by which they are expanded, must be regarded as the action of Fire; which, consequently, being external, and accidental, cannot exert itself upon Bodies, without offering them some degree of violence. Hence, therefore, all Solids would naturally endeavour to form themselves into little compact Masses, and when they were reduced to the smallest ones possible, would enjoy a most fix'd perfect quiet: Whilst on the contrary, they would be so constantly agitated by the action of Fire, that their parts could never possibly come to a state of rest. The last effect of cold, therefore, upon the Particles of Bodies, would be their most intimate union, and absolute rest: That of Fire, their dissolution, and perpetual agitation.

The substance of Body is condensed by cold. Hence a cold is proper to Body.

Does Fire and Cold, therefore, alone, affect the very substance of Bodies, whilst every thing else reaches only their constituent parts? Does perfect rest, in any part of space, produce the greatest degree of Cold? And should any place be perfectly free from Fire, so as not to possess the very least degree of it, would there of consequence necessarily follow absolute rest?

Heat and Cold, the principal agents upon Matter.

5. Hence it appears farther, that Pendulums growing shorter about the Poles of the Earth, will perform a greater number of vibrations within any given time; and their appended weights being condensed, will suffer a less resistance from the Air. And hence too does it not seem probable, that the Cold towards the Pole, and the Heat about the Equator, are one cause of the spheroidal figure of the Earth?

The figure of the Earth from Heat and Cold.

6. Again, Cold condenses all solid Masses, by reducing that very part of them, which we call Body, into a lesser space than it took up before; and hence their whole matter being more closely united, there almost always arises a stronger cohesion of the Mass in general; which is what we call strength, and firmness. From the same cause too, the particular Particles of which the Body is compos'd, are more strongly compacted together, nor suffer themselves to be so easily separated asunder, as they were in their former state; which therefore is a second cause of their stability. And lastly, as far as one can judge, the very constituent Elements of Bodies are render'd more dense by Cold, as well as the whole Mass; and this gives them the greatest degree

Density from Cold.

of strength, and was what we just now called acting upon their very substance. But, Gentlemen, what notion can the most subtle penetration form of ultimate Body? For my own part, I confess, all that I can conceive here is this, that any single Body, supposing it simple, is composed of lesser Bodies perfectly like the greater, and these again in the same manner of smaller, and so on beyond any limits that the mind is capable of fixing: That there is a certain principle implanted in some corpuscles by the great Creator, by which they are united and form'd into little Masses, which it is not possible for any natural, or artificial Power, to separate asunder; and which of consequence remain always the same, notwithstanding all the violence that can be exerted upon them: And lastly, that these may be concreted with one another, and by their reciprocal attraction, produce so firm a union, as will be very seldom destroy'd, and then only by some few particular causes, which will be able to effect nothing more upon them, than barely dividing them asunder, and reducing them again to their original state; for then they will be perfectly immutable as they were before. These few simple things, are all, that upon the most intent inquiry into the powers and operations of Nature, I have been able to come to the knowledge of. Hence we understand what were the Atoms of *Democritus*, the *Monads* of some Philosophers, the *Hylarchic* Principles of others, and the last Principles of Bodies of almost all Philosophers in general. Are those Particles therefore so solid, that they won't admit even Fire itself within them? And hence are they neither dilatable by any natural power, or reducible into a lesser space? And of consequence, does condensation and rarefaction affect only the corpuscles which are compounded of these Elements, and not the very Elements themselves? Be this as it will, this is certain, that both the Philosophers and Physicians have constantly observed, that all Solids in the Animal, Vegetable, and Fossil Kingdom, are strengthen'd by cold, and the condensation that arises from it.

A Duumv-
rate and vi-
cissitude of
Heat and
Cold.

Always and
every where
alternate.

7. The alternate vicissitudes of Heat and Cold seem to produce a continual motion and agitation in all the Bodies in the universe, and in all their Particles, as often as they succeed one another, inasmuch as the actions of each of them must necessarily bring about the effects already mention'd.

8. Now these seldom continue to act long upon Bodies in the same degree, but are perpetually changing, and when one begins to grow excessive, it is generally soon temper'd by the succession of the other, whose effects are quite contrary to the former. For if we diligently examine into the order of Nature, we shall find nothing more cautiously provided against, than that the same degree of Cold or Heat should reign for any considerable time. Is not the Earth, for instance, disposed in such a manner, with regard to the Sun, that at one time it may receive its rays in a more oblique direction, at others in a more perpendicular one, nor should ever remain for the least space of time in the same aspect? by which means, this perpetual change of Heat in the different seasons of the year, brings about very different effects. Nor is there a less variation produc'd in Heat and Cold by the alternate succession of day and night; for hence it comes to pass, that they seldom continue in the same degree, for so small a time as the space of an hour: Nor are the Meteors we observe in the Air, a less evident proof of this mutability. The Sun again, has no sooner parch'd up the Earth with its scorching Heat, and fill'd the Atmosphere

sphere with vapours and exhalations, but there very soon follow Clouds, Thunder, Lightning, Hail, and Rain, so that instead of that excessive Heat, there presently arises a very considerable Cold. From these considerations then, I can't but infer, that in every solid Body that exists in our World, there is a constant peristaltic or oscillatory motion of all the particles that enter into its composition.

9. It appears evident, now, that this reciprocal succession of Heat and Cold induces very different and more powerful alterations in Bodies, than either of them would do were they continued any considerable time in the same degree. By the same Heat, for instance, acting upon them a long while, Plants and Animals are rendered dry, and the remainder becomes more durable; and a constant Frost effects the same: Whereas if these very frequently succeed one another, there follows an intimate solution of bodies, which are hereby disposed to become volatil, and are in a great measure dissipated into the Air. But there would be no end, should I only hint at the effects that are hence produced.

Of great use to the world.

10. For this reason the wise Author of Nature seems to have ordained that such a vicissitude of things should be fixed, and unalterable; that thus the whole universe might remain in a perpetual motion, not only in the larger Bodies that compose it, but also in their most intimate and ultimate particles, that by this means the production, increase, state, decrease, and dissolution of every thing might be brought about by the same law.

Putting every Body into motion even to its most intimate parts.

11. But who, now, will pretend to determine the ultimate limits of Cold? Or where is that so intense, that it cannot be increased? There, you'll be apt to say, where there is no Fire. True; but it is impossible for us to find any such place; nor can the subtlest Artist with all his skill ever perfectly extract Fire out of any Body, or any part of space. Upon this head, therefore, we need not trouble ourselves with any farther Inquiries. May the ultimate degree of Heat, therefore, be more easily discovered? Nothing less; for we are here as much at a loss to find out the greatest quantity of Fire that may be contained in any given space, as we were before to assign any place that is absolutely free from it. The violence of that Fire which we see collected in the *Focus* of a large concave Mirrour, or a convex Burning-glass is apt to strike us with astonishment: But who knows how prodigiously this power might be increased, if the concave surface of the *Speculum* was vastly greater, and of a conoidal, or parabolical figure? Or if it could be made of a substance perfectly solid without the least Pore in it? Or lastly could it be formed of some matter of such a nature, that it would reflect the rays exactly in the same manner as they fell upon it?

The limits of Cold not to be determined.

12. 'Tis sufficient, however, for our purpose, if we can determine the different degrees which happen commonly here upon our Earth. And it is very easy now to inform ourselves, what alterations happen in the increase or decrease of Heat, and when it continues the same, by what has been already delivered: For here (as our surest guide) we have principally to regard the dilatation or contraction of Bodies, which by proper instruments may be readily ascertained without difficulty.

The degrees of it may be compared together.

13. In the mean while it must be confessed, that it is both an ingenious and difficult work to determine the quantity of Fire in any given place, so as to be able to express the proportion of it in numbers to any other known Fire.

And exactly enough be expressed by numbers.

It

It is easy enough, it's true, to perceive whether it is increased, or not; but to discover the degree of this augmentation, is vastly more difficult. It will appear, however, presently, that even this, hard as it is, is not impossible, but may be attained to by human industry. All these things now, seem so evidently to flow from our first and second Observation concerning the nature and presence of Fire, that I think they may be fairly taken for granted, nor will they be of small service to us in our chemical Inquiries.

EXPERIMENT III.

Common Air, is every way expanded by the least increase of Fire in its whole bulk, and in all its parts.

This the Philosophers were long ago acquainted with; tho' the illustrious Boyle principally set about the proof of it: Upon this head therefore we need not detain you.

The Air-
Thermo-
meter of
Drebbelius.

Improved.

Plat. II.

Fig. II.

The truth of this was sufficiently demonstrated formerly by the Thermometer invented by *Cornelius Drebbelius* of *Alcmar*; for this purely by the assistance of rarefied, or condensed Air, very evidently repels liquors from it, or attracts them to it. You see, for instance, by only breathing upon this Sphere, I make the coloured fluid in the neck to fall lower: But as soon as I leave off it begins again to ascend: And upon the approach of a warm hand towards it, you perceive the same effect is instantly produced. Now these Instruments may be rendered so sensible of the very least degree of Heat, that by the help of them you may plainly discern the perpetual Syftole, and Diastole of the Air, which is never observed to be at rest. The construction is as follows. Let your vessel that is to contain the Air be made of thin and very clear glass, and formed of two Segments of a Sphere joined together, and so contrived that the two great opposite Segments AB, CD, may be pretty near one another: And here the larger the vessel is, and the less spherical the Figure, if the Air can but be easily contained in it, and freely pass in and out, the fitter it will be to demonstrate these minute differences. To this vessel then let there be connected a slender pipe EF, open at F, and as narrow as it can be made, without hindering the free passage of the Air with all its force. If this Instrument, now, being full of common Air, as it will be of course if it is exposed to it, has its lower orifice F immersed in a vessel filled with water deeply tinged; and you then gently heat the glass ABCD, you will presently observe bubbles of Air pass out of EF, by the mouth F, which will continue to do so, as long as you keep the Fire near the glass. When, therefore, you have forced out a sufficient quantity of Air, which must be but a few little bubbles, remove the Heat, and the coloured liquor will immediately ascend into the neck; and if you have taken care that too much Air was not expelled, it will get no higher than about the middle of the pipe EF; and then you will have the pleasure of observing the perpetual risings and fallings of the liquor in the neck, at the smallest changes of Heat, and Cold. And this will be always the more evident the thinner the glass is, the larger the vessel ABCD is in respect of the Cavity of the pipe EF, and the nearer the Segments AB, CD, are made to approach to one another; as is easily demonstrated by Hydraulics. You readily apprehend, now, why I prefer the Segments AB, CD to a Sphere in this Instrument, and why I would have them

them but at a small distance: For you see plainly that by this means the surface of the included Air being much increased, either Heat, or Cold will be more readily communicated quite through it. But that the truth of this may appear evidently to you all, see here I take this chemical glass with a large belly, and very slender neck; which being now full of the common Air, we breath at this time, I thus invert, and immerge into this Water. You observe now, that as I bring the Fire near the glass, the included Air runs out of the neck in bubbles through the Water. You conceive therefore, that there is less Air at present in the vessel than there was before, and that in proportion to the quantity of bubbles that were forced out. I'll now remove the Fire: and you see how instantly the Water ascends into the neck; and perceive farther, that as I bring the Fire nearer, and remove it by turns, how the Water alternately rises, and falls, so that it scarcely remains a moment at rest.

C O R O L. I.

This expansion of Air by Fire extends to a prodigious space, nor can easily be determined by any Experiments. For a proof of this, heat a hollow spherical glass in a glass-house furnace till it is just ready to melt, then hermetically seal it there, and afterwards carefully cool it by degrees, and you will find that even then it is not perfectly void of Air: For if you sink it under Water, and there break off the end of the neck, the Water indeed will rush in with great violence, but still there will always remain a space at top full of Air, which is able to sustain the whole weight of the Atmosphere.

Fire in reality expands Air.

Hence, therefore, we evidently learn, that though the intense Fire of the furnace rarefied the Air to a prodigious degree, yet it was not able totally to expel it. It is probable indeed, that a greater degree of Heat would still have rendered it more rare; but it is equally probable that it can never be expanded *in infinitum*, and that therefore, there will always remain some Air in the very strongest Fire. From some Observations made on this head the famous *Des Amontons* has ingeniously inferred that the space into which Air is dilated by the degree of Heat necessary to make Water boil, is a third part greater than that which it took up before. I am aware of a plausible objection, that may be made to the inference drawn from the last Experiment, and that is, that the Air which thus collects itself at the upper part of the glass, when it is immersed in the Water, does in reality proceed from the Water, whilst it is forced into the neck by the pressure of the Atmosphere: For as this repletion is successive, the first portion of Water that enters, is in reality, in a more perfect *vacuum* than that of *Boyle*; and consequently the Air which is mixed with that Water, will endeavour to disengage itself, will rush into this *vacuum*, collect itself there, and thus hinder the perfect repletion of the vessel. To this I answer, I will allow you indeed that some Air may have come into the glass, in the manner you mention, but then it must be with this limitation; that all the Air that thus extricates itself out of the Water into the empty glass, will be always again absorbed by that Water from whence it came, and then the whole cavity will be perfectly filled with Water; for this the accurate *Mariot* has happily discovered, and I shall evidently make appear when I come to treat professedly of Air: Since therefore (in this case) the Air will not be absorbed, and the Sphere be filled, it is plain that the space that will not admit the Water, does really contain

But does not totally expel it.

contain a portion of true Air, which the force of the Fire dilated indeed, but was not able perfectly to expel; which was what I asserted.

COROL. 2.

The difference between the expansion of Air, and that of Iron.

If we consider now the dilatation which was before demonstrated in Iron, how very small is that, even in a Fire so strong as to heat it red hot? How great on the other hand do we observe the expansion of Air from a small degree of Heat? We found indeed that Iron is capable of being presently extended by a very gentle Fire; but then, this was not to be discovered without the assistance of an Instrument; whereas the difference of the rarefaction of Air by the same Fire, is vastly remarkable. No Body that we are acquainted with is more easily affected by Fire than Air; nor any one put into fusion with more difficulty than Iron, or which is the same thing, distended to its greatest dimensions.

COROL. 3.

The expansion of Air by the least degree of Heat, discernible.

Hence we may have the pleasure of determining the least increase of the Heat of Air almost to any given measure, that can here be of service: For we have nothing to do, but to make the spherical Segments in the Instrument above described very large in proportion to the capacity of the pipe, and to make this very long; for then, the least difference of Heat will be very sensibly discerned in the pipe.

COROL. 4.

The greatest natural Heat in the Air.
† See Plate V. and VI.

But whereas the greatest natural Heat of the Air, even in the most sultry Dog-days, is rarely observed to come up to the 90th degree in † *Fahrenheit's* Thermometer, hence we know exactly the limits of that Heat, which it will be found hardly ever to exceed. All its natural variation therefore in this respect will consist in its decrease below this degree. Hence therefore the use of the *Drebbelian* Thermometer is very easy, and very serviceable. But then you must take care to have always a Barometer near it, in order to measure the different weights of the Atmosphere at the same time; for that must likewise enter into the consideration. By this means, then, and with very little trouble, you will be able to observe the smallest increases of the least degree of Heat.

COROL. 5.

Air is never at rest.

If we consider, therefore, the very easy dilatability, and contractility of Air by the very least augmentations, or diminutions of Fire, and at the same time remember that these are in a constant vicissitude; does it not evidently appear that this Air can never be at rest, but must suffer a perpetual agitation in all its parts, by which even its very ultimate particles must be kept in a constant oscillation? And this will hold as true in what we call the open Air, which is only kept within its bounds by the weight of the incumbent Atmosphere, as it does in that Air which is perfectly confined in a close vessel.

EXPERIMENT IV.

Air, by the least decrease of Heat, is every way contracted, both in its whole bulk, and in all its parts.

This was evident in all the instances we gave under the third Experiment; for this contraction was always observ'd to follow, in proportion as the Fire was removed.

COROL. 1.

The spaces, into which Air is thus reduced, grow constantly less and less, so long as the Heat decreases; and consequently, there is no such thing as determining the least possible space that any quantity of Air may be contracted into, as it is impossible to free it absolutely from Fire; as has been already taken notice of. In the glass Thermometers of *Drebbelius*, exposed to a successively increasing Cold, this observation appears very evident.

COROL. 2.

The greatest contraction that is observed in any other Body from the most intense cold, is less than the condensation that the Air suffers from the very least decrease of Heat or Fire, that our senses are capable of discerning by any other method. And hence for this reason, likewise, the Air is the fittest of any thing to discover to us the quantity of Fire.

COROL. 3.

Again, any diminution of Heat or Fire, or the least augmentation of Cold, may be rendered visible, and adjusted to any assigned measure: For this is the converse only of the third Corollary of the third Experiment.

COROL. 4.

The use therefore of this Air-Thermometer, will be so much the more excellent, and easy, as the greatest degree of artificial Cold, and the intensest natural Cold of the Winter Season, have been very nicely determined by Observation.

An Inquiry into the greatest degree of Cold.

In the most severe Cold in the year 1709, the liquor in *Fahrenheit's* Thermometer was observed, in *Iceland*, as low as the first number; and I myself saw it one morning this year in our University garden almost down to number 5.

First natural,

As for the contrivances that have hitherto been invented to excite artificial Cold, no body has yet been able by the help of them to produce a freezing Cold in Summer, till there first appeared a congelation of Water, either in form of Snow, Ice, Hail, or Hoar-frost: For though some persons have come pretty near it; yet it would never succeed, 'till the season was grown considerably Cold, and inclining towards the freezing point, and thus rendered the Water cold, and fit for the purpose. There have indeed been a great many, and very laborious Experiments made use of, in order to produce the greatest possible artificial Cold. And it has long ago appeared by chemical Observations, that Salts, the very instant they are dissolved in Water, will excite a greater degree of Cold, than was in either of them before the mixture. Now the principal of these for this purpose, is the common purest *Sal-Ammoniac*; with which I made the following Experiment. I took four ounces of this Salt, and reduced it to a fine dry powder, and let it stand all night in a clean dry glass stopped very close with a cork. In this condition I put the glass with the included Salt, which was so secured that no moisture could possibly come at it, into some fair

Then artificial.

O

Water

Water that had stood a whole night exposed to the open Air; and by this means I brought the Salt, Water, and Glass exactly to the same degree of Cold. In the morning, then, I placed one of *Fahrenheit's* Thermometers in this Water, till the Cold of it had fixed the included liquor at the degree 53 above O; and then at once I threw the four ounces of the *Sal-Ammoniac*, into twelve ounces of this Water contained in a cylindrical glass, and with a stick I briskly stirred them about, and mixed them together; upon which the liquor in the Thermometer immediately fell from the first degree 53, to the degree 25; the same in the Air open standing at the same time at 51. Hence, therefore, it evidently appears, that *Sal-Ammoniac* mixt with Water in a subtriple proportion, will generate 28 degrees of Cold in this Thermometer.

Artificial
Cold for
producing of
Ice.

And of consequence, a Cold that will produce Ice may always be excited by Art, when the Heat of the Air don't make the Thermometer rise above the degree 60. For it is observed, that as soon as ever the temper of the external Air reduces the liquor in the Thermometer to the degree 32, then Water, too being equally cold begins to form itself into Ice. The colder therefore the Air grows from the degree 60 towards the degree 32, the more will the artificial Cold produced by this method exceed that which is necessary to turn Water into Ice.

And a
greater de-
gree.

When the Coldness of Water therefore is about the degree 32, this mixture will excite a Cold, which will sink the Thermometer almost as low as the degree 4. But now if we take some Water in a large vessel, and by this solution make it 28 degrees colder than it was before; and then place another smaller glass full of Water in this cold *Lixivium*, and by this means give this second Water as great a degree of Cold, as this *Lixivium*, which will remain cold a good while, can communicate to it; we may then, by mixing fresh *Sal-Ammoniac* with the Water in this second glass, whilst it stands in the first *Lixivium*, quickly produce even in the hottest weather a greater degree of Cold than was ever observed in our Country. And yet again, if we take the Ice that we may procure by this contrivance, and mix that with new cold *Sal-Ammoniac*, the Cold thus generated will be still more intense: So that by this method, we may, in the middle of Summer, presently excite a sharper Cold than that of the severest Winter.

The freez-
ing point-not
easily ob-
servable.

Give me leave, however, to mention one caution, that may here be of service to prevent your falling into mistakes, which is, that it is not so easy to determine that temper of the Air, which is just necessary to the production of Ice, as one may at first imagine. For Heat, and Cold, when they are once communicated to Bodies; remain in them a considerable while before they leave them: And the denser they are, the longer will they retain the Heat impressed upon them; as will be demonstrated in its proper place. And hence it comes to pass, that though the Air is cold enough to reduce the liquor in the Thermometer to the degree 32, yet there will not immediately be Ice upon the Water; for this being more than 800 times denser than common Air, will continue warm from the former Heat a considerable time after the Air has been affected with a new degree of Cold. If any person, therefore, desires nicely to inform himself in what temperature of the Air Water will begin to freeze, let him make use of the following method. First suspend your Thermometer in the free open Air; for I have observed, that if you hang it against a wall, or any other Body, the Warmth that is in them will have some effect upon it
When.

When you have in this manner exactly discovered the Heat of the Atmosphere by your Thermometer, expose a small quantity of Water to the Air in such a manner that the surface of it that is contiguous with the Air may be as large as possible; which is best effected by dipping a fine clean cloth in fair Water, and then hanging it open in the Air, and keeping it there some time. By this means, that upon the first freezing Cold, the cloth will grow stiff, and thus shew that the Water at that time begins to be hardened into Ice. And by this method, I have observed that Water will begin to freeze, if it is as Cold as the Air is when the Thermometer is almost at the degree 33; though it will not do so, if it is kept something warmer than the Air, by any Body that is near it, or by the largeness of its own bulk.

And hence it comes to pass that Hoar-Frost, which is nothing but a moisture congealed on the broad surfaces of thin Bodies, as Grass, Leaves, and the fine asperities of the ground, appears a good while before we see any Ice. And in the same manner as Winter comes on, this white Frost appears on bridges that are suspended in the Air, before there is the least sign of Ice in the Streets, or on the Water. But who don't plainly see that this is occasioned by the arch's not being contiguous to any thing else, and of consequence being every way exposed to the Cold of the ambient Air? And for the same reason it thaws there as suddenly. Whereas Bodies that are thicker, retain their former Heat longer; for as they can only receive the impression of the Cold by their surface that is in contact with the Air, they hence must propagate it gradually through their substance towards their Center of gravity; and by this means they successively acquire a greater and greater degree of Cold, till they have been so long exposed to the Air as to be equally affected by it quite through. And here, how much time is necessary for this purpose it is not easy to determine.

Hoar-Frost
a mark of
it.

From what has been said, therefore, upon this head it appears, that the limits of the most intense natural Cold that has been observed, have been found to descend to O in the Thermometer; whereas Art, by dissolving Salts in the coldest Water, could never reach below the degree 4, or 3.

The indefatigable industry, however, of the ingenious *Fabrenheit* has discovered somewhat yet farther in this affair, which before seemed quite incredible, and which I think well worth relating in the same manner as it was communicated to me by the Author himself, to whom all lovers of natural knowledge will be ready to make proper acknowledgements for this surprising Experiment.

Production
of a surpris-
ing Cold.

The severity of the Winter of this year 1729, gave him an opportunity of making some Experiments for the production of artificial Cold; and among the rest, it fortunately came into his mind to try what would be the effect of pouring Spirit of Nitre upon Ice, the Spirit being so strong, that its weight, to that of pure Water, was as 1409 to 1000, when the Heat of both was 48 degrees. He took, therefore, some Ice, and pounding it very small, poured upon it two ounces of this Spirit of Nitre; by which means there was instantly produced such a Cold, that the Thermometer being presently immersed in this mixture, the liquor subsided more than 4 degrees below O. This unexpected and very surprising event raised the curiosity of this excellent Artist, who could not rest till he had made some farther discoveries. He contrived, therefore, a Thermometer with Quicksilver sensible of the very least alteration of Heat, which he very nicely divided into parts that might be easily discerned,

The great
industry of
M. *Fabren-
heit*.

and constructed in such a manner, that O in the cylindrical neck should be 76 degrees above the bulb of the glass. The Spirit of Nitre, then, abovementioned being reduced to the same Coldness as the Air which was at that time 16 degrees, he poured seven ounces of it upon some Ice finely pounded; and the Thermometer immediately fell 30 degrees, viz. from 16 degrees above O, to 14 degrees below it. The Mercury in the Thermometer being then at rest, he poured off the fluid part, and to the remainder of the Ice which was not dissolved, and was now so very cold, he put fresh Spirit of Nitre; upon which the Thermometer sunk to 29 degrees below O. He had then no more Spirit by him, and therefore could not at that time prosecute this experiment any farther.

He poured, therefore, Spirit of Sea Salt that was 17 degrees cold upon some Ice beaten very small; and the Thermometer sunk in an instant to the degree 8 below O. Then decanting the liquor, he mixed fresh Spirit with the remainder of the Ice that was reduced to this degree of Cold; and the Mercury subsided to the degree $14\frac{1}{2}$ below O. Being pleased, therefore, with the agreeable success of these Experiments, the curious Author was resolved to carry them still farther, and therefore provided some of the same Spirit of Nitre. But the temper of the Air being then so altered that it thawed, he was forced to contrive a method to preserve an artificial Cold after he had produced it; which he did in the following manner. He got three vessels made of very thin plates of Iron, of a cylindrical figure, and almost $6\frac{1}{2}$ inches wide. In these he placed three cylindrical glasses of $3\frac{3}{4}$ inches diameter; so that the distance betwixt these and the sides of iron vessels was inch and a $\frac{1}{2}$; nor did the bottoms of the glasses come nearer the bottoms of the other vessels than by the same distance. These spaces, then, between the two vessels he exactly filled up with cotton, that the Cold might be retained the longer, nor might be too soon affected by the Warmth of the Air, when once it was produced. These three vessels, then, being thus prepared, the glasses were filled with pounded Ice, and in them were placed three glass Tubes of $\frac{3}{4}$ of an Inch diameter, filled with Spirit of Nitre, which was at that time 32 degrees warm; and the Water that ran from the beaten Ice was carefully poured off. This being done, some Spirit was put upon the Ice, and when the Thermometer applied to it would fall no lower, the fluid part was poured off from the remaining refrigerated Ice, and at the same time the Spirit of Nitre, that was reduced to the same degree of Cold in the other glasses by the affusion of this Spirit, was poured upon the Ice. After this, then, had been repeated in the same manner four times, the spirit of Nitre made use of being thus kept exceeding cold, and the liquor being carefully poured off from the Ice after every affusion of the Spirit, he observed that the Thermometer at last subsided to 40 degrees below O. And then, the very Spirit of Nitre being acted upon by so great a Cold, shot into fine sharp Chrystals about $\frac{1}{2}$ an Inch long, and being frozen as it were itself, required shaking with some force to get it out of the Tube. As soon, however, as this inspissated Spirit came to touch the Ice, they were both presently dissolved, and at the same instant the Thermometer sunk from the degree 37 below 40. By mixing pot ashes with the pounded Ice he was able to produce a Cold 8 degrees below O.

Now what person living could ever have had the least suspicion of such a *Phænomenon* as this? The greatest natural Cold has never been observed to
sink

sink the Thermometer below O; and then, all Animals, and Vegetables, that were exposed to it, died immediately: Art has increased it yet 40 degrees more: But if to 32 degrees, which is the point of freezing, you add 40 degrees, the Heat of the Air will be then so great, that we could not bear it long without the alternate interposition of some refreshment from a greater degree of Cold. Hence we see evidently, which one could scarcely have believed, that Cold, which is able to turn Water into Ice, may still have its power increased by 72 degrees. Now what would be the consequence, should Nature ever generate such a temperature as this? We find, that such strong Spirit of Nitre as was made use of in this Experiment would be congealed. We see Mercury is so condensed in it, that it takes up a space almost $\frac{1}{289}$ th less than it did before. We observe that this wonderful Body, in so vast a degree of Cold, and with this increased density, remains equally fluid, mobile, and expansible, as it was before. We know farther, that the substance of Mercury, from the degree 600, in which it begins to boil, to this degree 40 below O, will be contracted $\frac{640}{10782}$ parts of its whole bulk; and consequently may be rendered $\frac{1}{17}$ th specifically heavier, or lighter, by the Cold, and Heat, that we are at present acquainted with. Now these things we are absolutely sure of from Experiment; and hence we see that Mercury, as it is gradually condensed by Cold, approaches nearer and nearer to the weight of Gold. But who will pretend to determine, what farther degrees of Cold may be still produced, either by the powers of Nature, or Art, that lie hitherto undiscover'd? Who can describe the alterations that both Solids and Fluids would undergo, were they exposed to this degree of Cold? If we have a desire of promoting natural knowledge, let us prepare such a Cold as this, and then try what effect it will have upon the Bodies that we are acquainted with. By this means certainly we might come at an infinite number of useful discoveries, of which at present we must be silent. In the mean while, however, we ought to pay a due honour to the worthy Inventor of this Method, who has thus set us an Example, pointed out the way to us, and furnish'd us with proper helps for carrying on these inquiries to greater perfection.

The weight
of Mercury
incredibly
altered by
Cold.

COROL. 5.

And lastly, the converse of the fifth Corollary of the third Experiment, appears very evident, *viz.* that the Air is scarce a moment at rest, neither that which is open, nor that which is confin'd in any vessel whatever.

EXPERIMENT V.

Pure Alcohol of Wine is expanded every way in its whole bulk by a small increase of Fire.

For instance: Observe this glass vessel, which contains 1933 parts of this Alcohol. You see it terminates in this narrow Cylinder, which has been made with a great deal of care, that it might be every where equally wide. This whole Cylinder now contains 96 of those parts, of which the lower Bulb contains 1933, and is graduated with numbers corresponding to those parts. In the severe Cold of 1709, in one of the coldest parts of the world, the Alcohol was reduced to number 1: And yet, if the warmth of a Man in health is applied to the Glass, the Spirit will be expanded to the number 96, and fill the Cylinder so high.

COROL.

COROL. 1.

In this instrument therefore, the Liquor, considered in the state in which it was in the greatest observ'd natural Cold, may be dilated by the vital Heat of a healthy person to $\frac{1}{20}$ th part of its bulk. It is necessary, however, to take notice, that we here suppose the capacity of the Thermometer to continue the same, whereas, in reality, it will be increased, as appears by the second Corollary of the second Experiment.

COROL. 2.

The difficulty of determining the rarefaction of Fluids.

If we could exactly discover therefore the proportion of the capacity of this instrument in the most intense Cold, to the same when affected by this vital Warmth; we could then also absolutely determine the increase of the bulk of this Fluid by the greatest degree of Heat contained betwixt these two limits: For then the difference of these two capacities will help us readily to measure this dilatation.

COROL. 3.

Another cause of the figure of the Earth.

Shou'd the most pure Alcohol, therefore, about the Poles of the Earth be compared with the same betwixt the Tropics, what a considerable difference would there be in its hydrostatical weight in these two places? For it is plain, that all these Liquors are heaviest about the Poles, and lightest near the Equator. Is this therefore another physical cause of the compress'd spheroidal figure of the Earth; since a smaller bulk in one place, is equal in weight to a larger in the other, and they both tend with an equal force towards their common center of gravity?

COROL. 4.

Hence the Areometers are not perfectly exact.

From these observations we learn, that the same vessels fill'd with such a sort of Liquor, will not be so full by a good deal in the cold of winter, as they are in summer; for the firmer parts of the solid vessels are not so much dilated with the same degree of Heat as the contained Fluids are. And indeed, the Chemists have very often experienc'd the truth of this to their disadvantage, when they have in frosty weather fill'd their glasses quite full of valuable Liquors; for when they have afterwards been affected by the Heat of the Summer, they have penetrated through the stoppers, forced them out, and often burst the glasses themselves. Being now therefore made wiser by these inconveniences, they always leave an $\frac{1}{8}$ th part empty, when they fill them in the Winter; or else, warm both the Liquors and Vessels to as great a degree of Heat, as one may reasonably expect in the midst of Summer.

COROL. 5.

The vast rarefaction of Alcohol.

If Alcohol is made so hot as just to begin to boil, it is then observ'd to rise to number 174 in the Cylinder; and therefore is then increased almost $\frac{1}{11}$ th of its dimensions: Nay, in reality, it is at that time more dilated, as appears by what has been remark'd under the first Corollary of this Experiment. And here, by the way, give me leave to take notice, how much difference there is in buying Alcohol by measure in the depth of a hard Winter, and in the sultry

Dog-days, which is certainly very considerable. If we consider now that Alcohol in the most intense cold subsides 40 degrees below 0, and when it begins to boil, rises to 174 degrees above 0; it appears, that there may be a difference in its dimensions of 214 parts in 1933; and consequently, that it may be contracted or expanded to $\frac{1}{9}$ of its whole bulk.

COROL. 6.

✓ If you urge Alcohol still farther, so as to make it boil, there presently arises a vapour from the upper part of it, which expands itself in the superiour vacuum, and grows denser and denser every moment, whence the dilatation of it cannot be conveniently measur'd any farther. And as soon as the Thermometer is open'd at top, the rarefy'd vapour immediately flies off, nor can it be determin'd how much more it may be afterwards expanded.

Ebullition
puts a stop
to the
measure of
its expansion.

COROL. 7.

Alcohol, therefore, can scarcely ever be perfectly at rest: For if it is confin'd in a vessel, and has either a *Torricellian vacuum*, or Air above it, it is evident, that it will be continually dilated, and resolv'd into vapours; or contracted, and so condensed into Alcohol again; unless, by chance, the degree of Heat, or Cold, should constantly remain the same: Or on the other hand, if it is exposed to the open Air, it cannot be at quiet; but, as we took notice in the Air, will suffer a perpetual systole and diastole, so long as there is a succession of greater and less degrees of Heat in the Atmosphere; which is observ'd to happen continually, almost without intermission. But then, however, this agitation will be most remarkable, when either Heat or Cold grows excessive; which state seldom continues any considerable time. Lastly, hence the Physicians understand what certain and frequent oscillations must happen in the human Body from the Particles of Alcohol, when they are mixt with our juices; as they will be at one time compressed and heated by the action of the Arteries, at another, freed from this pressure, and of consequence, cool'd, in the Veins.

Alcohol im-
patient of
rest.

EXPERIMENT VI.

The most limpid, light, ætherial Oil of Turpentine, is every way expanded in its whole bulk, by a small increase of Fire.

This you'll see evidently in this spherical Glass, with this long narrow cylindrical Neck. You observe, that the Bulb of this is fill'd with Oil just to the beginning of the Cylinder. I dip this into Water, that is exactly as cold as the Oil, and you see it continues precisely in the same place. I'll now put this vessel of Water with the glass of Oil in it upon the Fire in this Chafing-dish: And now how evidently do you perceive, that as the Water, and consequently the Oil in the Glass grows gradually hotter and hotter, the Oil rises in the Neck, and scarcely remains one moment in the same Altitude? I have now kept the Water, as you see, upon the Fire till it boils; and now the Oil, you observe, is at rest in the Glass, neither ascends nor descends, nor would do so, tho' it should continue a good while in the boiling Water: Nay, I'll put more Fire about the vessel, and make the Water boil more violently; and yet you observe the Oil keeps exactly at the same height: Nor will this mercurial

Ebullition
gives Liquors
their greatest
Heat.

And the
compression
of Liquors.

rial Thermometer rise any higher, when once the Water comes to boil. For this beautiful discovery, the Philosophers are obliged to that very ingenious Gentleman, *Monsieur des Amontons*; the truth of which you have now evidently seen in Water, and it is continually found by Experiment, to hold good in almost every kind of Liquor. And here, the candour, which I feel within my Breast at present, and which I hope I shall always have the pleasure of, obliges me to acknowledge in this publick manner, that nothing has been of greater service to me in discovering the usefulness of Fire in the deepest chemical inquiries, or better help'd me to come at the knowledge of the properties of this Element, than this valuable Experiment of this noble Author. But I refer you to the fountain, the *Mem. de l' Acad. Roy. des Sci.* where you may have the pleasure of seeing what he himself has said upon this subject. There you will find that famous Gentleman has actually demonstrated, that when Water once comes to boil, tho' you urge it with ever so strong a Fire, you cannot make it afterwards grow any hotter. This valuable discovery, however, may be still farther improv'd, by a very curious observation of the industrious *Fabrenheit*; for he has found, that the Heat of the same boiling Water will be constantly greater, when the weight of the incumbent Atmosphere presses heavier upon its surface, and less, when the pressure of that is lighter. If we would therefore at any time nicely determine the degree of Heat in boiling Water, we must have a Barometer by us, to observe at the same time the weight of the Air; or else we shall not be able to ascertain it exactly. In the mean time, however, 'tis absolutely certain, that so long as the pressure of the Atmosphere continues the same, boiling Water will not grow hotter by any increase of Fire whatever: And with this limitation, the rule of *Monsieur des Amontons*, will always be found to hold true. When the difference now of the weights of the Atmosphere is 3 inches, then the difference of the Heat of boiling Water under these two pressures, is found to be about 8 or 9 degrees. Hence this Author evidently infers, that the more closely the parts of Water are compressed together by the increase of the incumbent Weights, the more Fire will be required to make them recede from one another; in which consists ebullition. And hence he makes this elegant deduction, that the Thermometer, by being immersed in boiling Water, will, by the degree of Heat it expresses, discover at that time the weight of the Atmosphere; and of consequence would accurately enough determine it at Sea, where the Barometers are not steady, if every degree of increase was made visible in the Thermometer, which may be accomplish'd with a great deal of ease. And hence, lastly, he observes, that our Atmosphere is so much the more heated by the Solar rays, as it is more compress'd, that is, the nearer it approaches to the surface of the Earth; and the less, the lighter the pressure is, viz. in the regions above us. And this is plainly confirm'd by observation; for the tops of the highest mountains that are nearest exposed to the heat of the Sun, and never obscured with clouds, are found to be so extremely cold, that the Snow lies there perpetually without being melted. Have you a mind to be witnesses to the truth of this yourselves? Under a Receiver in *Boyle's* Air Pump, place a glass vessel full of Water, heated to 96 degrees, and then gradually draw out the Air, and you will evidently perceive an ebullition excited in the Water, as the pressure of the Atmosphere is lessened, which will intirely disappear again upon the letting in of the Air. Hence, there-

therefore, by a Barometer fix'd in the Receiver, you may be able to determine what degree of Heat is necessary to make Water begin to boil under any given Weights of the Atmosphere; and by this means we may come at an infinite number of beautiful discoveries that we are at present unacquainted with. There is one thing more upon this head, that I think well worth mentioning, before I quit it, and that is this; Put some Water into *Papin's* Digester, and with the included Air stop it in such a manner that nothing can possibly come out, and afterwards make it Oil. The Water then will be expanded $\frac{1}{3}$, and the Air $\frac{1}{3}$; and consequently, the Water will be as much compressed, as if its pressure was increased by 10 inches of a common Atmosphere; and by this means Water acquires 30 degrees of Heat extraordinary purely by being made to boil in this Machine, for I here take no notice of the force it gains by the motion and attrition of the particles of Water and Air against the vessel, and among one another. What wonder therefore is it at all, that by this Machine are produced such prodigious effects? If you have a mind now to examine by a ballance the proportion of the expanded Oil in this Experiment, to the same in its natural state, you may compute it in the following manner: The Oil fill'd the Bulb of the Glass just to the beginning of the Neck, when the Water, Glass, Oil, and Air, had 52 degrees of Heat in *Fahrenheit's* Thermometer. When the Water boil'd, and the Oil would ascend no higher, the Thermometer was risen to degree 212, and the Oil was as high in the Neck as the mark which you see I have fix'd on it. If I now weigh the Glass fill'd to this mark with Oil that is 52 degrees hot, and then empty it as low as the bottom of the Neck, and weigh it again, I find pretty nearly the expansion of the Oil; which upon examination, appears to be a very considerable part of its bulk. I must caution you, however, that I have no regard here to the increase of the capacity of the Glass in this degree of Heat: But I have taken notice of this before, and therefore shan't mention it any more for the future. See *Exper. V. Cor. 2.*

And you need not wonder here, Gentlemen, that I determine the limits of the dilatation of Oil of Turpentine by boiling Water, which I did not do in the former Experiment. The reason is evident. Alcohol boils with a much less heat than Water; and as soon as ever it boils, its expansion cannot be measured any farther. *Exper. V. Corol. 5.* Whereas in Oil of Turpentine, which is much lighter than Water, an ebullition cannot be excited by the greatest Heat of boiling Water, but its surface will always remain at rest in this degree, in which therefore we may measure its dilatation.

Before I quit this Experiment, give me leave to take notice of a pretty remarkable *Phænomenon* that presents itself to our observation in this ebullition of Liquors. Alcohol, which is lighter, boils sooner than Water, in a *Ratio* which we shall afterwards assign; and yet Water, which is heavier, boils a considerable deal sooner than Oil of Turpentine. Is the cause of this the affinity there is betwixt Fire and inflammable Oils? Or is the specific Gravity of the boiling Liquid of consequence here? Or lastly, is it owing to a greater or less tenacity of the parts among one another? You will see by and by, what a vast deal of pains I have taken to resolve these Queries: And I think it will be evident, that they ought all to be consider'd, as well as the different pressures of the Atmosphere, which are likewise concerned in it. See the incomparable *Newton* in his *Opticks*.

Some surprizing
Phænomena
in the ebullition of Liquors.

EXPERIMENT VII.

The rarity
of boiling
Water.

Pure Rain-water, gradually heated by a gentle Fire, is every way expanded in its whole bulk, by a very small augmentation of Heat.

This you see evidently in this Glass, where its dilatation is $\frac{1}{85}$ of its whole dimensions: For from the degree of Heat 56, it always rises to the degree 214, in which it begins to boil; and then it remains at rest, and has acquired the dilatation mentioned.

EXPERIMENT VIII.

The rarity
of Mercury
in boiling
Water.

Mercury, by the application of Heat, is easily rarefied.

The truth of this is plainly demonstrated by this elegant Thermometer, which was made at my request, by that very ingenious Artist *Daniel Gabriel Fabrenheit*. The inferiour Cylinder of this Thermometer contains 11124 parts of Mercury, which in the greatest Cold observ'd in *Iceland*, reach'd to the mark 0, from whence upwards we compute the increasing degrees of Heat. If I immerge this in the Water in this vessel, and gradually heat the Water, you see the Mercury continually ascends till the Water boils; and then you observe it remains perfectly quiet at one number, viz. 212, and something more. Setting aside, therefore, the dilatation of the Glass, the Mercury at present takes up 11336 little spaces, of which in the greatest Cold it took up but 11124; and consequently, in this degree of Heat, is expanded $\frac{1}{52-25}$ of its whole bulk.

53

COROL. 1.

The rarity
of other
boiling Li-
quors.

In the same manner the strongest *Lixiviums* of Sea-Salt, Nitre, and fix'd alkaline Salts, are dilated by Heat; and in short, all Liquids that have hitherto been examined: So that Air, Alcohol, Oils, Water, saline Spirits, *Lixiviums* of Salts, Oil of Vitriol, and Mercury, are all affected by the very same law.

COROL. 2.

The cause that dilates all these Bodies passes through glass, and all other vessels, into the Liquors themselves.

COROL. 3.

And this same cause proceeds from what we universally call Heat, or Fire.

SCHOLIUM.

For the future, therefore, by Fire I shall always mean that Being, however otherwise unknown, which is endued with this property, that it penetrates all Bodies, both solid and fluid, and by this very action, extends them into larger spaces: For as on the one hand I am not acquainted with any Body in the whole compass of Nature that has these qualities, except what by every one is called Fire; so on the other, there never is Fire really present in any Body, but these two effects are immediately produced; and in proportion as this is increased, the extension of Bodies is likewise augmented. Now such a character as this is sufficient in Physics for determining and distinguishing particular natural Bodies: Nor indeed are there any other that will answer the same

same purpose, whatever your idle Philosophers may boast of their subtle speculations. It is our business therefore to observe with the greatest care, those properties that we are able to discover in Fire under this notion ; and of these the first seems to be this, that it exists in every point of time, and every part of space ; the truth of which I shall demonstrate by the following Experiments.

EXPERIMENT IX.

Take a thick cold plate of Iron, and in the sharpest weather, and coldest place, lay this upon another of the same kind, and equally cold, and let this, by the help of a weight, be press'd hard upon the under one ; then, let it be briskly rubb'd upon it backwards and forwards, and it will begin to grow warm, then hot, and in a short time will acquire such a degree of Heat, as to emit sparks of Fire, and at last the whole Mass will be as red hot, as if it came out of a large common Fire.

The first manner of producing Fire.

COROL. 1.

This production of Fire may be effected at any time whatsoever : Nor does it at all signify, whether the season is hot, or cold : Nay, in reality, the more compact the Bodies are render'd by Cold, you will, *cæteris paribus*, have the strongest Heat.

COROL. 2.

Nor is there any place hitherto known, where the same Experiment will not hold true. On the tops of the highest mountains, in the deepest subterraneous caverns, in the warmest parts of the world, and most frozen climates, the effect will constantly prove the same. I confess, indeed, that the Heat will be sooner and more strongly excited in dry places, than it will in moist ones ; but still, it may be always produc'd in this manner. And the same thing is observ'd to happen in every kind of solid Bodies whatever.

COROL. 3.

Nay even in *vacuo* Bodies grow hot by mutual attrition ; as evidently appears by the accurate observations of the ingenious *Haukeſby*, which have since been happily improv'd by my good Friend and Colleague the famous *James-Williams' Gravesand*, a Gentleman so form'd by Nature, and finish'd by Art for these abstruse inquiries, that by his discoveries, the boundaries of natural knowledge are daily enlarged.

COROL. 4.

But there is nothing more remarkable in the Fire produc'd in the manner abovemention'd, than that it penetrates into all Bodies, the densest not excepted, heats, expands, burns, and melts them ; and that it shines, grows excessive bright, and in short, has perfectly the very same effects that we constantly observe in true Fire. And we see here it is thus generated without any *Pabulum*, or any Fire that existed before by which it might be rais'd, which is commonly the case, Fire generally being lighted by Fire, and one Flame excited by another. Hence then, I think, we may fairly conclude, that this Being ought to be look'd upon as true Fire.

COROL. 5.

The first
cause of this.

In the mean time we learn by general observation, that the harder and more rigid the Bodies are that are agitated one against another, the more intense will the Fire be that is produced by their mutual attrition. Hence the very same Body, when it is rigider, or softer, acquires in this respect a very different degree of Heat. Iron, if it is taken out of the Fire when it is just ready to melt, and in the heat of summer suffer'd to cool very leisurely in the Air, will remain very soft and flexible; whereas, if you instantly throw it into cold Water, the Particles, that were before put in motion, and render'd flexible by the Fire, being now compacted together, and driven into closer union by this sudden contraction, the Iron becomes exceeding hard, rigid, and very elastic: But every body knows how much fitter Iron is for striking a light when it is harden'd by Cold, than when it is softer. If the vast hard *Axis* of a Windmill lies upon a rigid block, and the sails are whirled rapidly about by a strong Wind, Fire and Flame break out immediately; but if you take care to put Lead between them, there is not much danger of so great a degree of Heat. If you strike a Flint against a very hard piece of Steel, how certain are you of procuring Sparks from it? which would not be the case, should you strike it against a bit of soft Iron. And hence it comes to pass, that if you interpose any soft Body betwixt two hard ones, you can scarcely excite Fire by the strongest attrition, till this is consumed, and the Bodies come to rub one against another, and then you have Fire presently. If you take, for instance, two Plates of Iron, and oil them very well, you cannot by rubbing them together, make them conceive any very great degree of Heat; but when the surfaces of the Iron come to touch one another, they will soon grow excessively hot by the same agitation.

If Bodies, therefore, are alike in every thing else, the denser the matter is of which they consist, the fitter will they be for this production of Fire; which rule holds universally true: I say, if they are alike in all other respects; for Lead which is denser, but at the same time softer, will not by attrition yield so much Fire as Iron, which is lighter, but vastly harder: But if they are both equally rigid, then the heaviest is always most efficacious. Hence it appears, how that exceeding hard, and ponderous Wood, the *Sideroxylon* of the *Indians*, not only furnishes them with weapons, but by being rubb'd swiftly together, serves to kindle their fires whenever they want them.

The harder, then, and more dense the Bodies are, that are agitated one against another, the sooner will Fire be produc'd from them. Hence the collision of Steel and Flint excites Fire in the least instant of time; which is much longer generating from Bodies that are lighter, and not so hard.

COROL. 6.

A second
cause.

The principal physical power, however, that produces Fire by this attrition, consists in the Bodies being press'd very hard together, whilst they are rubb'd one against another. If you lay, for instance, one Iron Plate upon another, so that it may press the under one only by its own weight, and then with a certain reciprocal motion, agitate the upper one over the inferiour, you will be able to excite but a small degree of Heat. Lay a ten pound weight now upon the

the upper plate, and then move it with the same velocity as before, and a greater Heat will immediately be generated. And thus if you proceed you'll be surprized to find how the increments of Heat constantly correspond to the augmentations of the weights, if the agitations are performed with the same velocity. So that at last, if the pressure is increased to a very great degree, the strongest Fire may be produced in an instant. And the same also holds true in the Elements of Fluids themselves compressed together, as has already sufficiently appeared.

C O R O L. 7.

And, lastly, we observe, that the swifter the motion is of these hard Bodies one against another, the Fire excited by this attrition will *cæteris paribus* be so much the stronger, and the sooner produced; so that a slow motion scarcely generates any Heat, though a brisk one will raise a great quantity of Fire immediately. Hold a rope, for instance, very tight, and draw it gently through your hands, and you'll perceive no Warmth at all; but let it run through your hands with a rapid motion, and it will soon conceive Heat, and burn them: Press a steel blade hard against a threshold, or a grindstone, and it will scarcely grow warm if you move it but slowly; and yet if the reciprocal agitations are swift, you may soon produce a great degree of Heat: So that by holding a knife very hard against a grindstone whilst it is very rapidly turned round you may make it almost red hot, whilst the stone itself is hardly warm, because no part of the stone remains long in contact with the blade, but instantly moves from under it. Hence, therefore, the production of Fire may be increased in proportion to the augmentation of this celerity, and that without limits.

C O R O L. 8.

It follows, therefore, evidently from what has been said, that when the three causes just mentioned unite their power, there then may be the strongest Fire excited in an instant from the coldest Bodies. If two large, thick, circular plates of very hard Iron should be compressed together by a force of ten thousand pounds weight, and then be very rapidly agitated one against another, there would be the most violent Fire produced immediately in both the plates. This is evident in Windmills, where if the *Axis*, and block it lies upon are dry, and the wind is very strong, the attrition quickly generates both Fire, and Flame; though there, the motion is but slow, on account of the smaller Diameter of the *Axis*. Filings of Iron as they fly off burn the Workman's hands, and the raspings of Wood doe the same. In the deep parts, therefore, of the Earth towards the Center, where Bodies are vastly compressed by the incumbent weight, and consequently rendered exceeding dense, does the attrition excited there produce a very great degree of the strongest Fire? and consequently does the Heat there gradually increase more and more? See *Boyle of Cosm. Qual.* This is certain from what has been demonstrated, that it is impossible to determine the ultimate, or intensest degree of Heat, that may be generated by attrition: For though it were possible to discover what kind of Bodies were actually harder and more dense than all others; yet we could never possibly assign the greatest weight by which they might be pressed together, or the swiftest degree of motion with which they might be agitated. There never, therefore, can exist so great a degree of Heat, but that a greater may be still produced.

A third
cause.

This three-
fold cause
united.

The power
of Fire ex-
cited by at-
trition not
to be de-
termined.

EXPERIMENT

EXPERIMENT X.

Fluids inter-
posed be-
tween Bodies
retard this
production
of Fire.

If in the former Experiment any Fluid had been interposed between the Surfaces of the two Bodies thus densed, and pressed together, and had been continually supplied whilst they were in motion, they would scarcely have conceived any Heat; or at least nothing in comparison of what would have been produced by the same causes had that been away; the truth of which is confirmed by universal Observation. If I rub, for instance, the dry blade of this knife hard upon this dry whetstone, it presently grows hot, makes a noise, and often, as you see, emits sparks; whereas if I put a drop or two of Water, Oil, or Spirit between, the same cause, as you observe, repeated, does not produce the same effect. Every body knows that the Axle-trees of Wheels hardly ever grow hot if they are well guarded with grease; but if they and the Boxes are dry, they presently skreak, smoke, grow hot, and very often take fire: And for want of being secured in this manner whole Windmills have been frequently burnt down. But this never appears more evident than in the polishing of Glass: Neither the *Lens*, or the plate it is polished on, becomes hot till the interposed oily or watery liquor is consumed, and they both grow dry, but then, a very great Heat is excited immediately.

COROL. 1.

Soft rare
fluid Bodies
unfit to ex-
cite Fire by
attrition.

The softer, therefore, the more yielding, less elastic, and rarer any Bodies are, the less fit they are for producing Fire by attrition. And hence, as Fluids for the most part are possessed of these qualities, they are observed of all Bodies the least capable of exciting Heat in this manner; for they easily yield to any impression, and by this means slip out of the way, and elude the force of it. And this is found to hold true in the whole compass of nature.

COROL. 2.

And bodies
that lie loose
upon one an-
other.

And again, the less the force is by which any Bodies are pressed together, the less Heat will be generated by their rubbing one against another. This too is confirmed by every kind of Experiment without exception.

COROL. 3.

And Bodies
that are at
rest.

And lastly, if Bodies are moved softly one upon another, tho' they have all the other properties requisite to the production of Fire by friction, yet they will not generate any considerable Warmth; and if they are quite at rest, they will be reduced to the common temper of the ambient Air. This we see in vast heaps of Iron, where, though the Body is so hard, and that which lies at bottom is pressed down with such a prodigious incumbent weight, yet it conceives no more Heat than the very soft, rare, light Air, that surrounds it.

COROL. 4.

The absence
of natural
Fire thus
discovered.

From what has been observed, then, it seems to follow, that Fire least of all discovers itself by its effects in those parts of space where, first, there is either no body at all, or exceeding rare ones, whose parts are so loosely connected together that they scarcely cohere with one another; Secondly, where there is no cause to compress these Bodies together in these spaces; and thirdly, where there

there is no power to put them in motion so long as they continue there. With us, the *Torricellian Vacuum* is such a space as this: For if you take a glass Tube 40 inches long and closed at one end, and fill this quite full of the purest, driest Mercury made very hot, and then in an erect position properly immerge the open orifice in some more of the same Mercury, so that there shall be nothing but pure Mercury in the glass; there the Mercury will descend, and leave an empty space in the upper part of the Tube, in which, there does not appear the least sign of any heavy resisting Body; nay, if you compress the Mercury in the under vessel, that in the Tube will ascend and fill it perfectly full. Here, therefore, seems to be a space, where there is not the least attrition of any Bodies; and consequently, here will be the very smallest degree of Fire, so far as it depends upon this attrition. And yet, if you agitate this baroscopical Tube in the dark, a light will be hereby excited, which you will perceive in this *vacuum*, as that excellent Mathematician the great *Bernoulli* has so elegantly described, and explained. Hence every one will be ready to infer that, even there, there must be Bodies also. And indeed, that Being which thus penetrates the Glass, the Mercury, and the Air, must be uniformly distributed through that space; but it does not, however, any ways appear, that this, be it what it will, exhibits the least mark of any degree of Heat generated in this manner. Hence, perhaps, the light, that is thus excited by this concussion, is of the same nature with that which we treated of in our History of Light as a property of Fire. And, hence, we are led to imagine, that Light, and may be Fire itself, considered without the concurring action of any solid Bodies, passes freely through all parts of space, without discovering any effects of Fire that we are hitherto acquainted with. This, at least, is evident beyond all dispute, that as we ascend from the common surface of the Earth, and get to the tops of high mountains, where there are no Meteors to obstruct and disturb the equal action of the Sun, and where, therefore, its rays strike the Bodies opposed to them in the most direct manner, and with their utmost force, I say, there, we are not affected with Heat, but on the contrary always find a greater degree of Cold. And at length, when we are got so far from the Earth, and so near the Sun, that there are scarce any visible exhalations, or vapours observed to rise so high, then, Water, when any does reach thither, is congealed into Snow, and lies at the tops of these mountains all the Summer. So that it hence seems probable, that in those parts of space where there is no hard resisting corporeal substance to withstand the action of Fire, nor any thing which is capable of exciting attrition, there, Fire, though it is actually present, appears most quiet, and acts with the least efficacy: And since the altitude of the highest mountain is scarce equal to $\frac{1}{859}$ th of the Semi-diameter of the Earth, and yet there is so great an increase of Cold there, in this little recess from the Center of the Earth, this small approach to the Meridian Sun, and under this great pressure of the Atmosphere, what must we think would be the case, could these observations have been made a thousand times higher? Why, certainly, as far as we are able to guess by that poor little that we know of Nature, all motion seems gradually to decrease as you ascend higher and higher from the Earth, till at last, the uppermost regions appear to enjoy the most calm, and undisturbed rest. And this seems confirmed by this Observation, that the same

Pure simple
Fire.Scarcely dis-
cernable.

sort

Of the pure
Fire of the
Alchemists.

And He-
brews.

fort of trees, sprung from the same seeds, on the same mountain, and in the same situation with respect to the Sun, are always the largest at the foot of the mountain, and grow by degrees weaker and drier, the more you ascend. And this opinion will give us some light into the abstruse writings of the ancient Alchemists, where they tell, that in pure Fire there is the most perfect silence, and absolute rest, and that God resides in it; that from hence, however, are sent forth ministring Fires to quicken and move Bodies that would otherwise die through inactivity, and to dispose them to execute the pleasure, and appointment of the omnipotent Creator of all things. And, indeed, in this, they did but follow the opinions of the most ancient *Hebrews*, and the Sacred Writers. *Exod.* iii. 2, 3, 4. *xix.* 16, 18. *xxiv.* 17. *Lev.* x. 2. *Psalms* civ. 2, 4. *Ep. to Heb.* i. 7. *xii.* 29.

COROL. 5.

An exceed-
ing great
and sudden
Heat excited
by the at-
trition of
Metal
against the
lightest
Fluid.

Lastly, it appears evident from modern Experiments, that a surprizing Heat and Fire may be instantly produced in the coldest, hardest, and heaviest Bodies, purely by their attrition with the lightest, softest, cold Fluids, if the motion is exceeding violent.

If a large ball of solid Iron is fired from one of the biggest sort of cannons in the Winter, it will run through the cold Air 600 feet in a second, and consequently will meet with a vastly greater resistance from the Air, than from the most rapid wind; for when that moves only $22\frac{1}{4}$ feet in the same time it condenses the Air so violently, that it bears down every thing before it, tears up the trees, and breaks them to pieces, nor are houses, or towers able to withstand its fury, *Maraiotte* pag. 140. Hence it appears, what a very great attrition it must suffer purely from this cause; and yet this must be still increased considering that no part of its surface moves in a strait direction; for as the ball in its passage turns round upon its *Axis*, every point is continually describing a Cycloid. Now this ball, when it has run through its way with this rapidity, and comes to fall, is found to be perfectly hot; although through its whole passage it has constantly been exposed to fresh cold Air, and consequently has lost every moment something of the Heat it had conceived. Some persons may be apt here to object; that the Heat of the ball may be owing to the flame of the Gunpowder with which it is fired; but that can't possibly be, as it remains in it so infinitely short a time; certainly, scarce $\frac{1}{1080000}$ of an hour. Now who can believe that in so small a point of time this flame can communicate so great a degree of Heat to so solid a Body? But this may easily be accounted for, from that vast attrition that must arise betwixt the Air and the ball whilst it moves with this prodigious celerity, and acts, and is reacted upon by the Air with $27\frac{1}{11}$ times more force than that of the strongest wind that was ever yet observed.

The Doc-
trine drawn
from these
premises.

Since, therefore, it appears by every kind of Experiment, that Fire by the friction of any Bodies together may be quickly produced where it did not appear before, and that, at all times, in every degree of Cold, and in every place where trial has been hitherto made, supposing the three physical conditions which we mentioned before; I say, these things considered, I think we may thence fairly make a great many deductions, which will be of service to us in discovering the nature of this Element: Some of which by your leave I will here mention.

In

In the first place, then, by what we already know of Fire, it appears, that it must be always present in every part of space, though we are not at all times able to discover it, if we search for it only in the common methods: For the most accurate Thermometer evidently shews us, that there is always, and every where actually existing, a Heat greater than the intensest degree of Cold that we formerly described, though people are very apt wrongly to imagine, that there then remains no Fire at all in that place where the Thermometer is fallen as low as o.

Fire always
present in
every place,

Nor does Fire thus exist only in every part of space, but it is likewise equally diffused through every Body, the most solid, as well as the rarest: For if in the hottest day of Summer, or the coldest of Winter, you apply the most sensible Thermometer to a glass in which there is a *Torricellian Vacuum*, where one might possibly suspect there was nothing but mere Fire, and at the same time apply the same instrument to Gold, which is the solidest Body that we are acquainted with; you will find the degree of Heat and Cold perfectly alike in both, if they have both remained long enough in an Air that has in the mean time neither grown hotter or colder. These things seem strange, it's true, nor have I met with any Body that at the first proposing them, could readily come into them; but yet this just, and indeed, infallible method of making the Experiment, most evidently confirms the truth of them. In cold frosty weather I examined in this manner the *Torricellian Vacuum*, that of Boyle, Air, pure Alcohol, express'd Oils, distill'd Oils, Water, *Lixiviums* of various Salts, Spirits drawn from Salts by Distillation, Mercury, Feathers, Filings of Metals, Sand, and Lime, after they had been exposed to the cold Air, and found the degrees of Heat and Cold perfectly alike in all, without the least difference. This seems a surprizing paradox; but it is, nevertheless, absolutely true.

And in every
Body.

I have not, therefore, hitherto been able to discover, that in all nature there is any part of space, in which there is not Fire. Nor yet, has it ever appeared to me after the most laborious Inquiries, that there is any kind of Body, that has a power implanted in it by the Divine Being, by which it is able to attract this Fire thus equally diffused, and so unite it to itself, as to make the excess discernible to our senses. On the contrary, all the Observations that I have had an opportunity of making seem to evince, that where there is neither any degree of attrition, nor motion from the mixture of various Bodies together, there, Fire is most equally distributed through every part of space: Nor does it in the least signify whether these spaces are empty, or full, or with what kind of Bodies they are filled. I am sensible that every body will be here apt to cry out, that these are all Chimeras of my own brain, and that I assert things that are absolutely false, and contrary to common sense, which plainly teaches us that Iron in the Winter is colder than Feathers, and Mercury than Alcohol. But, Gentlemen, I have already given you a caution, that I am not here treating of Fire as it manifests itself to our senses by Heat, or Cold, but purely with regard to its property of rarefying Bodies, which after a good deal of diligent inquiry we have found to be its peculiar character. How it comes to pass that Alcohol in Winter appears warmer than Mercury, or rasped Ice, we shall endeavour to explain, when we have treated of the solidity, or rarity of Bodies with regard to Heat or Cold; nor can we do it now without breaking in upon the order of our subject.

The quan-
tity of Fire
as the
spaces it is
diffused
through.

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Seldom discovered as it exists in this manner.

The second thing I lay down in our doctrine of Fire is this, that this Fire, which is thus equally, and for the most part quietly diffused through every part of space, is scarcely ever taken notice of: For those things which constantly remain perfectly the same, nor discover themselves by any alteration, are commonly no more regarded than if they did not exist at all. If, for instance, there should at any time be such a degree of Fire, as should not produce the least change in either Fluids, or Solids, then no body would think at all of Fire, Heat, or Cold: But as soon as ever there was a small increase of Heat, so that Wax should become a little softer than it was before, then every one would immediately suspect that there was a new production of Heat, and Fire supposing them to know before that Wax would be reduced from its solid form to a fluid one by the application of Fire. And from this prejudice it happens that people generally think, that Fire is really generated by Art, or chance, whenever its effects are so remarkable as to render it more apparent than it was before.

And yet in this condition is always in motion.

In the third place, from what has been said it seems evidently to follow, that this Fire that is thus diffused through all space and every Body, is continually both moved itself, and puts other things in motion, although you suppose it ever so small. For what person living can assign the ultimate point of absolute Cold, or which perhaps is the same thing, the perfect rest of Fire? But the very least degree of Fire, Heat, or this rarefying power, immediately begins to expand every kind of Body, to remove their parts from their spontaneous cohesion, and, so long as it remains in them, to keep their Elements from their proper and natural union; which evidently demonstrates that a real motion is there excited. And hence it seems exceeding probable, that this Fire is contained *in vacuo*, and in the vacuities that are dispersed through the most solid Bodies, as in a kind of vessel, where it is frequently agitated, and always in action; and that hence it is of necessity continually producing certain Operations, the effect of all which principally tends to remove the Elements of Bodies from one another, that so the Fire may expand itself more equally. In the mean time, however, it is not less certain, that the Elements of corporeal matter constantly endeavour to unite themselves together more and more, to lessen the vacuities between their impenetrable particles, and consequently by the excess of their power to expel the Fire that is there continually endeavouring to dilate itself. Here, therefore, will be a constant action and reaction, between the Fire contained in these Pores, and the constituent Elements of the Bodies; the former tending always to separate these Elements from one another; the latter from a natural propensity perpetually attracting one another into the strongest union. On this account, therefore, the whole System of natural Bodies which the Almighty Creator has formed and disposed in infinite space, may be divided into Fire, which has a power of expanding every thing else, and the remaining Bodies which have a virtue implanted in them, whereby they constantly resist this separation of their Elements. And thus these two principles, the one of expansion, the other of attraction or association, exert themselves through the whole compass of nature, and are the cause of a vast number of corporeal effects. The energy, however, of these principles we cannot at present rightly understand from the ideas we have hitherto been able to form of them: This is the sole prerogative of that infinite

And repelled.

infinite Being, whose supreme Wisdom, at one view, perfectly takes in these and all other things, which his Almighty Power has created in such a manner as is not possible for mortal minds to comprehend.

The more intently, now, I examine this mysterious subject, the more plainly I am convinced, that Fire is not able to insinuate itself, into what we call the ultimate impenetrable Elements of Body, but that it is repelled thence whenever it exerts itself upon them, and always the more so, the greater the force is by which it endeavours to penetrate them: that some degree of attrition therefore may, nay, and must arise betwixt Fire and other Bodies: And that Fire itself does in reality never reside in the proper substance of Bodies, but only in the vacuities that will be left betwixt their Elements, let the Bodies be ever so solid. And certainly, the *ἀντιπυρία* of *Democritus*, or impenetrability as it is called by others, seems so proper to Fire, and every other Body, that it appears by every kind of Experiment to be perfectly inseparable from them.

Never penetrates the substance of Bodies.

As a fourth position in this doctrine we observe, that whilst this Fire thus residing within the Pores of Bodies, is not acted upon or moved by any other cause, so long it does not discover itself by any effect; for since it can go out of these passages again with the same ease with which it enters into them, it will not much vary its action upon the Body that contains it, as it seems to exist, and act every where in an equal quantity. That you may more clearly understand what it is I would here inculcate, observe the degree of Heat that this Thermometer, which is extremely sensible of Warmth and Cold, indicates at this time. I'll place this, now, against the mouth of this great Bellows, and you perceive what a prodigious wind comes directly upon the Thermometer. Don't you all expect now, that the force of this wind will produce a considerable degree of Cold; and that hence there will be a variation in this infallible Instrument? And yet you observe it remains perfectly at the same height. Here, then, we see evidently, that there was no degree, either of Heat, or Cold, generated by this means, which our senses were capable of discerning: For Fire, by reason of its exceeding rarity, is almost as easily conveyed through Air, when it is in motion, as when it is at rest. Indeed, was this Air agitated with an extraordinary violence, such a one as this Bellows is not capable of, in that case, by the attrition arising hence, might be excited a greater degree of Heat, as has already appeared; but then, this would be owing intirely to attrition. And hence perhaps it comes to pass, that the greatest storms, a few cases excepted, do generally *cæteris paribus* rather raise than sink the Thermometer. This, at least, I have long ago observed, that we have generally a very warm Air at the same time we have the highest winds, and the sharpest Frosts when every thing is perfectly calm. But you'll be apt to say, why then does the wind, and indeed the Air itself, appear so cold to our Bodies, especially when they are heated, so that every one very justly ascribes to them a power of cooling? And do we not find by undeniable Experience, that in a cold high wind, the Cold is vastly more injurious to us *cæteris paribus* than at other times, so that no person is able to bear it, but would soon have his limbs destroyed by a Gangrene? In answer to this, I acknowledge the truth of these facts, but at the same time assert, that the cause of them is very different from what people generally imagine. To account for this,

Wind don't produce Cold,

But rather Heat.

And yet it cools the Human Body.

this, then, we must observe, that no body is able to endure an Air that is heated to 90 degrees, but it soon becomes fatal to all sorts of Animals that we are acquainted with ; whereas the vital Warmth of the Human Body, as *Fabrenheit* has observed, will raise the Thermometer to the degree 92, and that of children often to 94. Hence, therefore, we are always warmer than the ambient Air ; and of consequence the garments that encompass our Bodies have a greater degree of Heat in them than if they were every way exposed to the open Air. Again, this natural Warmth heats the Air that is contiguous to our Bodies ; and therefore, if it is not disturbed by any wind, but remains quiet about us, this Atmosphere of our Bodies will be warmer than the Atmosphere of the common Air, and consequently we shall feel it warm, as it really is. When this warm Air then, that every way surrounds us, is dispersed by the wind, and a colder Air is applied to us in its room, there immediately is excited a real Cold both in our Lungs, and on the surface of our Bodies, that are exposed to it : And besides, the Heat that is communicated by us to our clothes is at the same time blown away, and fresh Cold is continually received by them, and thus applied to our Bodies : So that, in reality, we are nearly in the same circumstances as if a man should perpetually shift his clothes, and put on fresh ones that were just come out of the Air. It appears, therefore, from these considerations, that though wind does not actually generate any degree of Cold, yet it is capable of cooling the Human Body by thus carrying off the warm Air with which it is encompassed, and bringing fresh colder Air in its room. But as this Observation may be of exceeding service in Medicine, give me leave to illustrate it yet farther by an Example. Let us suppose then by exercise, disease, or some other cause, the heat of any person in his clothes, and in a serene Air to be 100 degrees ; and that of the common Air at the same time to be moderate, *viz.* about 48. Now you easily conceive that the clothes that are about his Body, will in a little time be pretty near as warm as his Body ; and that the Air which remains quiet about his clothes, and his head, will be considerably warmer than the degree 48 ; for I have often observed, that the Thermometer has been raised at the distance of 4 feet purely by the Warmth that has exhaled from a man that was hot, and fallen again when the person removed farther from it. Suppose, therefore, the person's clothes, and the surrounding Air, to be heated to the degree 60 : His Body then will be perfectly encompassed with this temperature, his vessels, and humours relaxed suitably to this degree of Heat, and his exterior Nerves will be just affected with a sense of the same. Let him be exposed, now, to a wind that moves 6 feet in the second of an hour ; and then all this heat of the ambient Air, and his clothes, will be removed in that time, and a Warmth of only 48 degrees will be applied to his Body on every side, and consequently his external parts will be 12 degrees colder than they were before : And since we suppose this wind to continue constantly the same, his Body must in a little time grow cold in its inmost parts ; as the constant application of this external Cold must every moment necessarily destroy as much of that Heat, which is generated by the vital actions. Thus, therefore, we have an evident solution of this *Phænomenon*, which otherwise, indeed, appears a paradox.

Not a
Thermo-
meter.

For if now, instead of a human Body, you place a Thermometer in this Wind, the Heat of the Liquor in the Thermometer, and that of the ambient Air,

Air, will be exactly the same; and hence, whether the Air that encompasses this Instrument remains perfectly at rest, or is constantly changed, the Liquor will still continue exactly at the same height; and consequently, the greatest Wind will not produce the least degree of Cold in the Thermometer; unless there is at the same time some alteration in the temperature of the Air in the place the Wind blows from. Now, from what has been remark'd, you, Gentlemen, who consider the human Body in a medicinal view, will easily understand, how nothing produces severer diseases, or is more quickly fatal to the healthiest, nay, and the stoutest Bodies, than exposing them to the Wind, when they have been heated with motion, and are ready to dissolve with Sweat; especially, if they are grown hot by a violent exercise in a cold Wind, and then remain quiet. Hence often arise Asthma's, that are never got rid of, *Angina's*, Pleurifies, Peripneumonies, Gout, and Rheumatism. A plain proof of this, likewise, we see too plainly in those persons who unhappily labour under an exceeding weak and tender habit of Body: How prodigiously do these suffer from the slightest Wind, or least breath of Air, if it comes only through a crack of a window, and is but little colder than the temperature of the chamber in which they live; especially, if that has been always kept pretty nearly the same by the help of a Thermometer, than which I know nothing more injurious to a good constitution.

The use of
it in Physic.

In the fourth place then, from what has been now said, and which we shall not repeat for the future, we may reason something of the nature and action of Fire: For if two dense, hard, and very elastic Bodies are rubb'd one against another with a great force, and a brisk reciprocal motion, then all the parts of these Bodies will every moment be closely compress'd; and as they are rigid, they will strongly resist this pressure, whence will arise an exceeding swift, and very powerful contraction and expansion, or a kind of quick vibration, such as we observe in Chords when they are very tense. How great these vibrations are, we see evidently in an elastic metal Bell, if it receives but one stroke upon it. Does not the whole Body of this, vastly large, as it is sometimes, expand and contract itself through all its substances in an infinite number of *Ellipses*, and that, for a very considerable time? And when the attrition that we just now described is excited, with what force, violence, and celerity, are the elements of the Body compressed, agitated, and relaxed, to their very inmost Particles? What a *stridor* is produc'd from this attrition, so acute, that the Ear is not able to bear it; a certain demonstration of the greatness of the vibration? We conceive, therefore, that whilst the Body suffers this agitation, compression, and relaxation, there must be an exceeding rapid motion in all its Particles, as all Chords perform their vibrations so much the quicker, the more elastic, and shorter they are, and the harder they are strained: But those three circumstances concur here all together. Now as this is beyond all dispute confirmed by Experiments, so I think it is not less evident, that the Fire, which in the mean time resides in the pores of these Bodies, and exerts there a power of expanding them in all their dimensions, and is likewise repelled by the contractile, resisting force of the expanded Body; I say, that this Fire must now, by the action of this attrition, be necessarily every moment most violently compress'd and relax'd in these vacuities. Hence, as from that property of expanding every thing which we took notice of before, Fire seems of all Bodies

The action
of Fire ex-
cited by at-
trition.

to be the most elastic, it appears that its proper force and motion must thus be prodigiously increased. For this reason, therefore, we conceive, that both in the Bodies thus agitated, and in the Fire contained within their Pores, there will be excited a motion exceeding great, and that will continue a considerable time. But farther, this cannot happen, but the surrounding Fire from both these causes must be agitated likewise, and that, so much the more violently, the nearer it is; for it has already appeared, that Fire is equally diffus'd through quiescent Bodies, and Space, which is neither capable of motion or change, and perhaps acts equally too. The ambient Fire, therefore, must likewise follow the concussions of that intercepted in the *Meatus's* of the Bodies thus rubb'd together; and of consequence, must be driven backward and forward. And this vibration seems to continue as long as that which is produc'd in the Bodies by this attrition, or till the oscillations of the Fire itself are reduc'd to rest, or a motion equal to that of the Fire in the Spaces or Bodies round about it. But since the same causes that agitate these Bodies must add a new motion to the Fire also, besides what it had before in common with all other, hence its force must be likewise increased: And as the expansion of Bodies is the proper effect of this force, it will of consequence presently discover itself by this effect. Thus far, therefore, we may comprehend the power of Fire, consider'd purely as excited by attrition: And the solution of a great many *Phænomena* we meet with here, will be hence easily understood.

By which
some *Phænomena*
are
understood.

1. Why do elastic Bodies chiefly generate Fire by attrition? Because they alone oscillate in their Elements. 2. Why do the most elastic Bodies produce most Fire, as we see in the hardest Steel briskly struck against a rigid Flint? Because the vibrations here are the swiftest and greatest. 3. Why do the softest non-elastic Bodies generate the least Fire? Because they have no spring in them, nor restore themselves again, nor oscillate backwards and forwards. 4. Why then will Lead rubb'd forcibly against Lead produce a very great degree of Heat? Because the ultimate Elements of Bodies are expansile and contractile by Fire, and from their own nature, tho' the larger Bodies that are composed of these Elements, have a cohesion of parts that is less resisting, and will easier give way. Hence it appears, that the elasticity of these Elements, which is common to all Bodies, and may be changed by Heat and Cold, is different from that by which Bodies resist an impulse, and restore themselves to the same form they had before the stroke. 5. Do not Fluids, therefore, generate Heat by attrition? Most certainly, if they are elastic; but with difficulty, if they are not. Hence Water will not easily grow warm by attrition. Nevertheless, if non-elastic Fluids are forc'd through very narrow canals with a vast *impetus*, they will conceive Heat by this attrition; because the ultimate Elements of these seem likewise to be somewhat elastic: But if the Pipes are elastic through which the Fluid is impell'd, then a still greater degree of Heat may be excited. Hence, our elastic Blood being violently propell'd through elastic Arteries, is hot whilst it circulates in a healthy Body: But when the Blood by any means becomes of a more watery disposition, and consequently less elastic, the Heat that is produced by its circulation will not be so great: Which is likewise the case, if the spring of the Arteries becomes weaker. 6. Why does the interposition of a Fluid, when Bodies are rubb'd together, hinder, or diminish, the production of Heat? Because the force impress'd is

eluded by the slipperiness of the Fluid. 7. Does therefore an elastic quality in Bodies increase the action of Fire upon them? Vastly; as appears from what has been just observed. 8. If the power of gravity determin'd Bodies less towards one another, what would be the consequence with respect to Fire? Then, we should scarcely perceive any of its effects: This we experience in the deepest pits, and on the tops of the highest mountains. 9. How does it happen then in very deep places, where the Air is always at rest? Why there, at the same depth, there will always be the same degree of Heat and Cold, tho' it will be different, at different depths, according to the various nature of the Earth that in those particular places surrounds and warms it: The truth of this is confirm'd by some elegant observation made in the Well of the Observatory at *Paris*. 10. Why does the percussion of Steel against a Flint, yield the largest and most vivid Sparks in the coldest weather? But there would be no end, should I mention every thing that is constantly occurring, whilst one's thoughts are engag'd on this subject. In short, therefore, Gravity, Elasticity, and Fire, seem to be the three principal of the universal or common causes of the actions of natural Bodies; and when to these, likewise, is added attrition, a great many *Phænomena* that are common to them all, may be easily understood.

From what has been premised, we infer, Fifthly, that if the densest, and most elastic Bodies of all, lying in the deepest parts of the Earth, and vastly press'd together by the weight of the incumbent ones, should be agitated one against another with the utmost degree of celerity, there would by this means be generated the most violent Fire. And hence it seems exceeding probable, that at the center of the Earth the Heat is most intense; and that it decreases gradually as you remove farther from it, till it becomes least of all at the boundaries of the two Planets. Let us suppose the Earth and Moon to be Bodies of the same nature; then in the center of the Earth and Moon will be the greatest degree of Heat, which will lessen by degrees, till you come to that part of space between these spheriodal Orbs, which terminates the action of both their powers. It appears, therefore, absolutely impossible, that any Birds can fly from us to the Moon, or from thence to us, as some Philosophers have asserted; or that they can exist in the profound Abyss. And what we have said of the Earth and Moon, will hold equally true in all the rest of the Planets. And hence it seems likely, that heavy Bodies are disposed only about the Planets, and perhaps about the Suns or fixt Stars, and thence by degrees grow so rare and light, that at last the resistance they yield becomes insupportable, if any at all: That the quantity of Fire there, however, is equally great: That this Element, therefore, may possibly not be affected by the power of Gravity, but be absolutely indetermin'd to any part of Space: That hence, of itself, it may have no other power than that of an equable expansion every way, without any particular direction to one place more than another: And that on this account, it may scarcely produce any effects in those superiour regions, as there is no agitation of dense, elastic Bodies one against another, to cause there any attrition. And as the motion and tracts of the Comets are not yet accurately determin'd, does not the path of these wonderful Bodies lie through these Spaces between the Planets, and Suns, where they meet with scarcely any resistance?

The Ratio
of Fire, and
where it is
greatest and
least.

Birds can't
bear the
temperature
of the high-
est part of
the Atmo-
sphere.

It

Some other
circumstan-
ces increas-
ing the Heat
rais'd by at-
trition.

It appears, farther, in the Sixth place, that those Bodies which have such large Pores interspersed through them, that Air, Water, Spirits, and Oils, may easily enter into them, and be expell'd again, are the least fit to generate Heat by attrition: Whereas those on the other hand, whose substance is so closely condensed, that their vacuities will admit nothing but pure simple Fire, must, if they are thus agitated, give a great degree of motion to the Fire contained within them. If we suppose, then, the Surfaces of two Bodies in contact to answer one another so nicely, that nothing but mere Fire shall be able to insinuate itself between them, when they are thus fitted together and put in motion; then, if they are rapidly mov'd one upon another, the Fire, which can alone interpose itself, will be agitated too: And from this cause again, the Heat will be augmented. And farther, if the agitation of these Bodies is so excessively rapid, that neither Air, nor any thing else can keep up with it, except the Fire that is dispersed through the Air, and other places; then, it seems exceeding probable, that this Fire will rush into these Spaces that are thus alternately empty, and fill'd again with this prodigious celerity; and thus more Fire will be collected in that Space which is nearest the Surface of these Bodies, than was there before; which will therefore be another cause of the production of Fire by attrition. And lastly, if the Elements of any hard Bodies are connected together by the firmest cohesion, and at the same time the Fibres and *Strata* form'd of them are exceeding short, and very tremulous; then, their vibrations will cause in Fire a very swift and strong agitation, and they will be able by a brisk attrition, to produce a vast degree of Heat in a very short time. The motion, therefore, that Fire acquires by these means, must certainly be prodigiously great.

Why does
Fire quit a
rarer Body
sooner than a
denser one.

It remains, now, carefully to inquire in the Seventh place, whether there is really observ'd in Bodies, any power by which they are able to attract Fire, so that the more solid substance they contain, the more Fire will of consequence be united with them? In quiescent Bodies, that this is not the case, is past dispute; for by Experiment, it constantly appears, that there is neither more nor less Heat or Fire in the *vacuum* of *Torricellius*, than there is in Gold, when they have both continued a good while in a place of the same temperature. But by the attrition we have spoken of so often, do Bodies acquire a kind of magnetic virtue, by which they are then capable of attracting Fire, and retaining it a considerable time when it is once united with them? I have taken a great deal of pains to answer this question; and this at least, I have evidently observ'd, that the rarer a Body is, the sooner it will be heated by the same degree of Fire; and that when once a Body is heated, the denser it is, the longer it will be before it is cold; and the rarer it is, the sooner. Hence, then, it seems to follow, that there is, in reality, in the solid Mass of Bodies, something like an attractive power, with regard to Fire; especially, as the same observation holds equally true in elastic Bodies, and those that are not so. In *Tschirnhausen's Focus*, the Fire is vastly intense; and yet, if with an Umbrella you cover that side of the Glass which is towards the Sun, the Heat will at once vanish from that place in the Air, where the moment before it was so excessive: Whereas, if a piece of Metal had been heated by the same Fire, it would have retain'd its Heat for a long time. If one vessel full of Air, and another of Water, had been expos'd to the same Heat, the Air, may be, in this
Heat,

Heat, would be a thousand times rarer than the Water heated to the same degree; but then the Water would retain the Heat so much longer, as it was longer in acquiring it, so that possibly the Air would grow cool a thousand times sooner. From these observations, however, I think we can fairly conclude no more than this, that the denser the Bodies are that are exposed to Fire, the greater difficulty it has to penetrate into them, and to disengage itself from them again; for this is all that experience certainly demonstrates: Nor does it appear with sufficient evidence, that this *Phænomenon* is really the effect of any other cause. Indeed, if one might be indulg'd a conjecture on this head, one would be apt to surmise, that when Fire enters into denser Bodies, it causes a concussion in their very Element, and puts them into vibrations, which are larger if they are less dense, and of longer continuance, if they are more so; and that these, as long as they are in action, agitate the Fire that is contained within them, in the same manner as it happens to elastic Bodies by attrition: Upon the most careful examination, however, of this matter, I have not been able hitherto to discover by observation any such thing as a magnetic power in Bodies with regard to Fire.

In the Eighth place, I observe farther, that the hardest, and most solid Bodies being penetrated by a very small degree of Fire, and heated through all the Particles of their whole Mass, are mov'd and agitated to their very inmost substance; as appear'd plainly under our first Experiment. When, therefore, the same Bodies are heated perfectly through by attrition, they will be constantly agitated in the same manner. And hence again, these *Stamina* being thus all tremulous together, we conceive that they must produce a friction among themselves so long as this motion continues; and consequently, must be agitated in the same manner as if this attrition was external. On this account, therefore, they must move the Fire contain'd within them, and attract, collect, and retain it a good while within their solid Mass. And then again, these filaments of the Bodies are reacted upon by the Fire, and thus too, suffers an attrition from it. From all these causes then, Heat will be sometime retained in Bodies when once it is communicated to them. And indeed, that great Philosopher *Robert Boyle*, long ago made it appear by Experiment, that a solid piece of the coldest Iron, laid upon a cold Anvil, and briskly hammer'd with cold Hammers, would, purely from this compressive force, and its own recoiling elasticity, grow so hot, as to kindle Sulphur that was thrown upon it: And again, that an iron Nail driven up to the head in a piece of hard Wood, would, by being struck upon with a cold Hammer, immediately grow exceeding hot, when once it could enter no farther, tho' the Hammer itself would continue cold. And he farther demonstrated the same thing in filing of Iron, where the Iron will acquire Heat, tho' there appears none at all in the File. See those valuable Treatises of his, *Of the Mechanical Production of Heat and Cold*.

Heat excited by percussion alone.

From these observations, therefore, we see in the Ninth place, that there may, by this means, be a great deal of Fire produced, where we are certain nothing more happens than the elastic Iron's being compress'd by other elastic Iron, and its restoring itself again between every stroke of the Hammer: And yet there will be here so great a collection of Fire, that Sulphur being sprinkled upon the Iron, will be kindled into a Flame.

Purely by the vibrations of elastic Bodies.

R

Tenthly,

From a simple stroke.

Tenthly, then, we conceive, that when once such an elastic Body is thus heated by percussion, it will for some time retain this oscillation in its compressed and recoiling Particles, and by this means continue the motion of Fire: As we see a Chord, when once struck, will tremble a good while; and a Bell, from one single stroke, will continue its sonorous undulations a great deal longer.

Fire is not actually generated by this means,

In the Eleventh place, it seems of consequence to examine whether this Fire that we have thus mention'd, as produc'd by attrition and percussion, is really generated *de novo* by these vibrations of the Particles, and did not exist before: And again, whether the parts thus vibrating do so wear away their own substance, that the Particles of the Body itself, thus abraded and agitated, become real Fire; and consequently, whether other Bodies may thus by attrition, percussion, and vibration, be actually chang'd into true Fire, and thus Fire be created of what was not Fire before? For my own part, I confess, this, to me, seems impossible. For I have demonstrated, that Fire exists in all places. I have made it appear, that it is equally diffused through every part of Space. I have prov'd, that it may be produc'd by the attrition of any Body whatsoever. And it is evident, that when it is once excited, let the manner of its production be what it will, it is always absolutely the same, and discovers immediately that property, which is peculiar to Fire and inseparable from it, and belongs to no other Body in nature besides. It is not at all probable, therefore, that Fire is continually generated *de novo*: But it seems likely, that when it is once created, it then continues always to exist, and that in the same quantity; tho' in all the actions abovemention'd, it undergoes such changes, in respect of its motion, rest, collection, dispersion, and direction, that it sometimes discovers itself to our senses, whilst at others it lies concealed beyond their penetration. And if a person carefully considers the things I have already offer'd concerning the marks and production of Fire, both as they stand separately, and as they give light into one another, I can't but believe, he will find they plainly confirm my opinion, and shew the fallacy of the other: For who does not see, that by the attrition and percussion of a hard elastic Body, Fire may be put in a greater motion, than it was in before? And who will deny, that this will likewise agitate other Bodies in a greater degree, when it is thus put into a swifter agitation itself? Who don't easily perceive, that Fire alone is able to keep up with the exceeding rapid motions of the most solid Bodies, and of consequence, must be there collected? And who doubts, but that in all these cases, so much Fire is really brought hither from the neighbouring places in particular, as now exists in this place more than did before? For the motion of Fire from one place to another, don't seem at all more difficult than that of any other Fluid. But as soon as ever it is collected from a larger Space, and more closely reduc'd into a less, it must of consequence appear to our sense, as tho' it was really created a-new, both on account of its quantity, and of its effects.

The conclusion.

In the Twelfth, and last place, give me leave to mention what I have taken notice of already, *viz.* that in every part of the known world, where there is the greatest degree of Cold that either Nature or Art produces, Fire does actually exist, and that in a very great quantity: For either by attrition, or percussion, the strongest Fire may be excited there in the least instant of time. This we see evidently by striking a Flint against a piece of Steel; and this the

Thermo-

Thermometer infallibly demonstrates, which we know certainly never suffers the least variation, when it is apply'd to Spaces, or Bodies of the same temperature. I think, therefore, Gentlemen, I have now, by Experiments, and the Corollaries drawn from them, pretty intelligibly explain'd to you the first physical manner, by which that Being may always and every where be certainly excited, which has a power of penetrating, and expanding or rarefying every thing we are acquainted with, Space only excepted: But this we plainly made appear before to be universally called Fire. We now, therefore, begin to get a little light into its hidden and mysterious Nature, and consequently, have some encouragement to prosecute our inquiries.

EXPERIMENT XI.

If Fire, explain'd as above, and now known by its power of rarefying, putting in motion, and insinuating itself into every kind of natural Bodies, is collected in any Space, or Body, so that it becomes perceptible to our senses, it then immediately begins to move itself by this power, and expands itself every way from the center of this Space, or Body.

That you may the better conceive what I mean, and at the same time see the proof of it, let this leaden Bullet be immersed in boiling Water, and after it has remain'd there till it has acquired the same Heat with the Water, be pulled out again by this Thread by which it is suspended. It then throws out the same degree of Heat from every point of it, with regard to our senses, has exactly the same effect upon the Thermometer plac'd at the same distance on any side of it, and by every circumstance indicates an equable dispersion of this Heat or Fire. Again, observe this red hot Iron just taken out of the Fire, does not the Fire look equally lucid and bright, and exhibit the same Colour in every part of it? And it warms us all equally, that are at the same distance all around it. It has evidently, likewise, the very same power of fusion, exsiccation, and burning, on every part of it. And which is the strongest proof of what I asserted, all Thermometers, let them be immersed in what Liquors they will, if they are plac'd at the same distance, will immediately discover the same temperature, by either expansion or contraction: And indeed, this is evidently confirm'd through the whole compass of Nature.

COROL. I.

It appears, therefore, that this is the property of Fire, that its parts, whilst they expand or move themselves, tend equally towards every part of Space, and consequently, are not determin'd to one point more than another. This, I confess, seems somewhat surprizing, and not easily intelligible; and indeed, this idea differs very little from the idea of rest. I'll endeavour, therefore, by a simple Example, to explain what I mean, a little more clearly. Suppose a hollow Sphere perfectly empty, and then conceive another Sphere a hundred times less to be plac'd in the center of it, and its parts to have such a power, that by equably receding from one another, they may perfectly fill up the larger Sphere: By this means then, you will have a true motion in all the parts, and yet the whole Mass thus mov'd, will be perfectly indifferent, and indetermin'd to any particular side. We conceive, therefore, from the

The proper
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Fire.

foregoing Experiment, that the Fire that resides in our Air always expands itself, and is compress'd by the same law, if no other cause intervenes.

COROL. 2.

The computation of this Fire, with regard to its force and quantity. Pl. III. Fig. 1.

If you'll give me leave now to call the circumstance of Fire, describ'd in the preceding Corollary, its State of Stagnation; then the force of stagnating Fire will be as the Spaces in which it is contain'd; and consequently, the communication of this force from it, will be as those Spaces. Suppose the Globe A full of Air, hotter than the other surrounding Air contain'd in the larger concentric Sphere B; then the quantity of Fire, and its active force upon any part of the circumscrib'd Sphere, will be to the whole, as the Space on which you suppose it to act, is to the whole Space circumscrib'd: But this, in any case, the Geometrician may easily compute; and therefore, with regard to this property of Fire, the case is very evident.

COROL. 3.

By an Example. Fig. 2.

For the easier conceiving of this, let us suppose the geometrical Globe A full of Fire, and in contact with another equal one B. From the center of the first C, draw the Tangents CD, and CE, to the Globe B. Then it is plain, that none of the Fire in the Globe A can, upon our supposition, come at the Globe B, except through the Sector CFG. Now the proportion of this to the whole Globe may be geometrically found *quam proxime*, as also the magnitude of the Cone CDE, and the spherical Segment DIE; and consequently, the quantity of Fire communicated to this Segment. These demonstrations we may be easily furnish'd with from the Geometricians: It is sufficient to our present purpose, just to have mentioned them.

COROL. 4.

An exact determination of it. Fig. 3.

These things being understood, let us now suppose some physical cause to arise, which has a power of impelling all the Fire contained in this Sphere in parallel lines, and so of determining it towards one particular part. We then immediately conceive, that its whole efficacy will be directed that way, so that it will pass through the Cylinder EFGI, and all of it fall upon the Sphere KGBI; and consequently, will exert its whole force upon that Sphere. The effect of it, therefore, in this direction, will be to the former, as the whole is to that part, and as this parallel direction is to the diverging one; from the combination of both which causes, its force will be very considerably increased. But the quantity of Fire being doubled, its efficacy will be vastly augmented: For in 32 degrees of Heat, Water will freeze; in double the number, *viz.* 64, the Air grows very hot; in 92 degrees, which is tripple the first, the Heat will exceed that of the Blood of a person in health, and an Air so hot would be fatal, perhaps, to every kind of Animal; in 192, which is 6 times the first, the Heat will come near to that of boiling Water, and would be able to dissolve and destroy all the parts of every Animal whatsoever. Since now the *Area* of a great Circle of this Sphere is to the whole Surface of the same, as 1 is to 4; hence the Fire in the Basis of the Cylinder abovementioned, will be 4 times more condensed than it was in the Surface of the Sphere before; and therefore, its force thus united, will be so much augmented. If we could

nicely

nicely, therefore, discover how the expansive power of Fire is increased in proportion to the smallness of the spaces into which it is condensed, then we should be able to finish the computation: For if this was as the *Areae* themselves, then its force would be four times greater on account of the quantity, and four times on account of the expansion, and consequently, sixteen times more violent from both causes together. We must endeavour, therefore, to determine if possible, by Experiment, this expansive power of Fire in respect of its density; for it is probable, that this is exceeding great; and consequently, that this direction of it in parallel Lines is of prodigious efficacy.

EXPERIMENT XII.

Now, if we turn our eyes every way to discover a cause that is able thus to determine the action of Fire into a Parallelism in our Air, the Sun certainly seems principally to offer itself as a being endued with a power sufficient for producing this effect. For that vast Globe, which the learned discover to be 13431 times greater than the Earth, and almost 12543 diameters of the Earth distant from it, as it appears by every kind of argument to diffuse its Light and Heat in right Lines, must in respect of its vast distance be considered as acting upon us in parallel Lines. It is not necessary here to cite those Arguments from Optics, Catoptrics, and Dioptrics, which no doubt you are acquainted with, by which the Rays of Light that flow from the Sun are demonstrated to proceed in right Lines, if they meet with nothing to interrupt them; and that then they are directed again in the same manner from that point of the obstacle upon which they fall. Give me leave, however, to mention one Experiment that occurs to me, which I think is an absolute proof that all the Rays, that either proceed from, or are determined by the Sun, affect the most strait direction; and that is this. Suppose it to be twelve a clock in a cold Winter's night, the Moon to be at the change, and the Heavens to be perfectly serene. Let any one then look up to the Sky, and he will see nothing lucid in that immense space, besides the Stars. Of the Heat, and Light of the Sun, there will nothing at all appear in the whole Hemisphere, except that inconsiderable quantity which the Planets borrow from that Luminary, and reflect to the Earth: And yet we are certain, that the Rays of the Sun at that very time, strongly enlighten all this Hemisphere, except that small Cone, whose Base is a great Circle of Earth, and its *Axis* 114 Diameters of the same; which small portion is all, of that vast space, that is included within the shade of the Earth, and consequently is not illumined by the Light of the Sun. It appears evident, therefore, beyond all dispute, that let a place be ever so brightly enlightened by the solar Rays, yet the Light will not be discerned by a person situated in such a position, that a right Line cannot be drawn from the Body of the Sun to his eye; except these direct Rays should first fall upon a Body by which they might be reflected to it. And the same thing is, nearer at hand, perceived in a chamber so nicely shut up that the least discernible Light cannot enter. For if you then make a very small hole towards the Sun, and by this means let its Rays into the room, you will in this place have only one lucid Cone, whose *Apex* in the hole, and its base projected *in infinitum*. Now if you take any Body perfectly black, and oppose it to the Base of the Cone, there will, then, no Light at all appear in the room,

The Sun determines
Fire into a
Parallelism.

room, except to an eye placed within the illumin'd Cone; for if it is placed on one side it will be nothing at all, though at the same time the Cone is exceeding lucid. I confess, indeed, if we look at it sideways we may discern a kind of weak Light in the Cone; but then you will easily see, that this must proceed from the dust that flies about in the Air, and so reflects the Rays of the Sun that fall upon them; which was it away there would not appear the least Light at all. And this is evidently observed to be true, when by chance, for this has been the case, these particles are so disposed that they will not repel the Rays of Light. By this argument, then, we are induced to believe, that the Sun has a power of making the particles of Fire, deflect from their natural tendency, which is from the Center to the Circumference, and determining of them in parallel Lines.

If we consider, again, that all objects which are visible by the means of Light, though obscure of themselves, immediately begin to shine, or appear, as soon as ever the Rays proceeding from the Sun fall upon them in a right direction, and grow invisible again the instant that this is prevented, then the same thing will be still farther confirmed. And again, if we rightly conceive, that the solar Rays falling upon a perfectly plain *Speculum*, and reflected thence by certain laws, only illuminate that part towards which the reflexion happens, this doctrine will be more fully established. But this Catoptrics certainly and evidently evinces; and moreover teaches us, that one Ray of Light, proceeding from the Sun in a right Line, and falling upon a pure *Speculum*, will be thence reflected to such another Glass in a right line, and repelled again by this in the same manner, and so on, and that this single Ray, after so many reflexions, will still retain its lucid property, though it will never be seen but in a right Line drawn from the lucid point of the last reflecting *Speculum* to the eye. Since, therefore, this happens in the whole image of the Sun, as well as in one single point, it is evident that that power of the Sun by which it determines Fire in parallel right Lines must always exert itself so long as this emanation and reflexion continue. But as soon as ever this luminous Body withdraws itself, this rectilineal direction immediately ceases, and Fire is then again left to its proper tendency, and enjoys its own natural expansive power. For this reason, therefore, the Sun ought to be looked upon as the director of Fire.

But, again, if we consider, that the vast Body of the Sun on account of its prodigious distance appears only a lucid Orb, whose Diameter takes up but $\frac{61}{43200}$ or $\frac{1}{708 \frac{12}{61}}$, or 30'. 30" of a great visible Circle of the Heavens, we shall easily see, that the Rays projected thence in respect of that little space which falls under our Observation, may be fairly regarded as parallel. And lastly, as a farther confirmation of this Doctrine, let us observe that in Optics, Catoptrics, and Dioptrics, we always suppose the Rays to come from the Sun in a parallel direction, in computing their refractions, reflexions, and the directions they move in; and yet, we can hence very accurately determine the true points of their *Foci*, reflexions, and directions, so that the *Phænomena* we observe in them, very nicely correspond with the demonstration.

From all these Observations, therefore, thus succinctly collected, it appears very evident, that the Sun is such a cause as will instantly determine the

matter of Light residing in our Air into a Parallelism, as often as it can exert its power upon it without any impediment.

But it has been always observed, that these lucid parallel Rays of the Sun produce Heat in the Bodies to which they are thus directed. And, hence, what has been just now demonstrated of Light, will appear as evidently true of Heat. And since we here speak of that Heat which is discovered by the Thermometer, we infer farther, that the same things will hold good of true Fire likewise, as we have hitherto explained it. We have now, therefore, found out the true reason why the Sun can very considerably increase the power of Fire, discoverable by its expansion, purely by this parallel determination, without any addition of new matter, without any supply of Fire from the body of the Sun itself, or any production of Fire from something that was not Fire before. And this, if I am not mistaken, is a discovery of the utmost consequence in a chemical Treatise of Fire.

Perhaps you may ask, now, why don't a lighted Candle then, since it emits its Rays of Light in a right direction, warm the place too that it illuminates? To this I answer, because this little radiant Cone does not act in a Parallelism, but diffuses its Rays in a kind of Sphere, and hence does not propel the Fire in the room to one part more than another, but every way equally. But even in this case, if you approach so near to the candle, that, on account of the small distance, the Rays may be considered as almost parallel, you will then immediately be sensible of Heat.

Thus, then, I think this difficulty intirely vanishes; especially if you consider at the same time, what I have observed already concerning the wonderful diversity of Light, and Heat.

COROL. I.

Whenever, therefore, this rectilineal impulse of the solar Rays, which thus give Fire its parallel direction, is by any means impeded, this Parallelism immediately ceases too, and that very moment the parts of Fire are equally expanded towards every side: Hence it easily appears, that this Parallelism was the only cause of all its former power. For let *Vilett's Speculum* be directed to the Sun at noon in a perfect clear day, and an iron rod be placed in its violent *Focus*, and be actually melted down; and then, whilst it acts with this vast power, let such an opaque Body be interposed between the *Focus*, and the Sun, as will shadow the whole *Area* of the Glass, and that intense *Focus* will instantaneously be destroyed, though the Air between the *Umbrella* and *Speculum* remains equally warm, that is, contains as much Fire as it did before, the Sun continues to shine equally bright, and nothing more happens than this parallel direction being prevented. Nor was there, as persons may imagine, more Fire between the *Focus*, and the *Speculum*, whilst the Rays of the Sun fell directly upon it: For in fact, one does not discover there any greater Heat, except what proceeds from the reflexion. There is a prodigious difference, therefore, betwixt that Heat which Fire yields from the attrition of Bodies, and that which is produced in the Air by this solar Parallelism: For the former continues a good while; the latter vanishes immediately. If a solid Body, however, is heated by the Sun, it will by reason of its solidity retain the Heat a considerable time.

When this Parallelism ceases, Heat ceases likewise.

The

The proper
manner of
building
Green-
houses.

The truth of what I have asserted, some Gardiners have experienced much to their prejudice, in their Greenhouses where they preserve their Plants in the winter season: For if the windows of these, by which they let in the Warmth of the winter Sun betwixt the hours of ten, and two, are so disposed that the Rays cannot reach to the ceiling, but tending downwards leave a space between the ceiling, and that part which is shone upon, that does not receive any of the solar Rays; then *cæteris paribus* there will be always in that place the greatest Cold. And, hence, there will be a cold moisture continually collected there, which falling upon the Plants frequently destroys those that are of a more tender nature. These Winter-houses, therefore, being built full South, should be furnished with windows (which, if possible, should reach quite down to the pavement, and be very clear) erected at an Angle of 34 degrees 30' from a perpendicular; and the ceiling should be built slooping in such a manner as to make an Angle of 20 degrees 30' with a Line drawn horizontally from the top of the windows towards the opposite wall; in those countries, I mean, where the elevation of the Pole is $52\frac{1}{2}$ degrees. The reason of this construction may be easily come at by the help of Astronomy, and the doctrine of Dialing: Brevity obliges us here to omit it.

COROL. 2.

The propor-
tion this Fire
bears to the
former pro-
duced by at-
trition.

The greatest Heat that the Sun ever naturally produces in our Air, and the Bodies heated by it by means of this Parallelism, is considerably less than that which is generated in a healthy man by the vital actions. For this frequently raises the Thermometer to the degree 92; that hardly ever to 84, and then never continues long in that degree, but quickly abates. It is necessary, however, to caution you, that I here speak only of that Heat which is observed in open places purely from the direct Rays of the Sun, without their being any ways reflected, or collected: For clouds, by reflexion, and aqueous Globules formed in the Air, by refraction, may very much increase the action of this Fire. But, however, even in this case, Fire never was known to be raised to such a degree by means of this Parallelism, or these natural reflexions, or refractions, as to be able to set Fire to Alcohol, Oil, Sulphur, or Gunpowder; unless, perhaps, Lightning may be an instance of it, of which, hereafter. And these Observations hold true of the natural Heat under the Equator itself, and every part of the Torrid Zone. Hence, therefore, it appears, that the greatest power of the Sun is not capable of heating any Bodies we are acquainted with to such a degree as to kindle them into flames, and consume them, and thus to produce spontaneous Fires, except, by means of Lightning alone. And it is farther evident, that the most scorching Sun cannot excite so much Fire in the hottest parts of the World, as may be quickly generated by a moderate attrition of very cold Bodies in the coldest: For if Iron is rubbed against Iron, it will soon grow so hot as to be able to set fire to Sulphur, or Gunpowder that is thrown upon it; and yet, even then, the Iron does not begin to emit any Light. Hence, again, we perceive it is not at all strange, that some Bodies are very lucid, though they give very little Heat; nor is it, we see plainly, a necessary consequence, that a Body is very hot, because it gives a great deal of Light: For the Light of the Sun, when it is upon the *Meridian* in a clear Winter's day affects the eyes so strongly, that it renders them quite blind for a considerable

a considerable time ; and yet its Heat, at that very time, is so weak, that it is not able to melt a thin piece of Ice suspended in the open Air, and directly exposed to it, as I myself have observed this Winter. The image of the Sun reflected from polished Gold, Silver, Brass, Iron, Tin, or Glass, is intolerable to our eyes by reason of its excessive brightness ; and yet it does not excite the least degree of Heat, that we can perceive, either by our senses, or the Thermometer. And hence, again, I infer, that there is a vast deal of difference betwixt the nature of Light, and Heat ; Lustre, and Fire.

COROL. 3.

The Supreme Being, therefore, has wisely provided that the Bodies of Animals, and Vegetables, even the tender ones, should not be destroyed by the direct force of the Sun. Direct I say, lest any one should imagine that I design to include that too, which proceeds from the reflexion, and collection of its Rays, which may thus be prodigiously increased ; for by this means it sometimes becomes so intense, that it renders places uninhabitable : Of this the Island *Ormus* has long been an instance, where the high mountains of white Salt, in a certain position to the Sun, by their whiteness so reflect, and unite its Rays, that at that time no body is able to live there. The same excessive degree of Heat, however, does not continue a great while, but is in a short time tempered by a succeeding Cold.

Scarcely
destroys
Bodies.

COROL. 4.

If the Sun should ever irradiate the Atmosphere of our Earth, at a time, when all the Corpuscles that float about in it, were disposed to an equable transmission of its Rays, it would then drive all the Fire in the Atmosphere into parallel Lines, except that portion that was included within the conical shade of the Earth. But there are a great many different reasons that makes it incredible that this should ever be the case, and, therefore, it appears exceeding probable, that very extraordinary reflexions, refractions, collections, and dispersions of the solar Rays perpetually happen there. And hence, the force and action of the Sun, both upon our Atmosphere, and Earth, will every where be found surprizingly different : But, in those places, that lie beyond the limits of our Atmosphere, the Fire thus directed by the Sun, seems to be always as the spaces themselves, if they are not at too great a distance from one another.

Is not the
same in dif-
ferent places,

COROL. 5.

Hence it seems exceeding likely, that the same degree of Fire is scarcely ever observed in different places : For whether you consider the various aspects of the Sun with regard to the Earth ; or the different nature, and motion of the Bodies that float about in the Atmosphere ; or the different properties of the very same, at different heights ; and many more such like circumstances : you will find that nothing seems more cautiously provided against, than that there should be the same force, and effect of Fire in different places. The efficacy, now, of these causes will be manifest by the following Experiments.

On various
accounts ;

EXPERIMENT XIII.

Chiefly from
the various
Colours of
Bodies.

If this Fire, thus determined by the Sun, falls upon Bodies that are exceeding black, its Heat will be retained there a considerable time. On this account, therefore, such Bodies grow sooner hot, and acquire a greater degree of Heat from the same Fire, grow dry in a shorter time when they have been wetted with Water, and burn much more readily than any other. We need go no farther for the proof of these assertions, than daily Observation. Take a piece of cloth died a very deep black; another piece of the same cloth, but white; a third, scarlet; and others of different Colours; and hang them up in the Air, and Sun, and you'll find that the black will grow warmest, and much sooner than any of the rest. And of the others of different dies, those always acquire Heat slowest, whose Colours are most vivid, and affect the eyes most strongly: for the white, and scarlet are longest growing warm; and the rest so much sooner as their Colours are less bright, as we see evidently in the weaker Green. And this, those people that live in the hottest countries are well acquainted with; for they find, that if their outward garment is white, it best secures them from the Heat of the scorching Sun, whereas if it is black, it suffocates the Heat, and makes it more troublesome. And it is a common Observation of the manufacturers of Woollen-cloth, that if a parcel of wet cloths are hung up at the same time, and are equally exposed to the Sun, the black will presently grow warm, reek, and dry; the white will retain its wet a long time; and the others will dry so much slower, as their Colour is brighter. Hence, again, white garments, when they are exposed to Heat retain their dampness much longer than others, and thus too keep the Body cool.

It has, yet farther, been observed that black Bodies take fire, flame, and burn, much easier with the same Fire than Bodies of any other Colour. Shavings, for instance, of very white wood will scarcely receive a spark struck upon them, so as to keep it in; but if you burn them to a black coal, the powder of this will easily support it, and be soon kindled all over by one single one. In the same manner a spark won't keep a-light any considerable time in a piece of very clean white linnen; whereas, if it falls upon the same when it is reduced to tinder, which is a sort of exceeding thin black coal, it will spread itself all over it. Nor would even Gunpowder itself, so soon take fire, were it not for its blackness; as we see evidently in the powder of very white Nitre rubbed with Sulphur. The Gardeners too have long observed to their disadvantage, that white Earth will hardly grow hot, except just on the surface; whilst the black conceives so great a heat, as to burn the very roots of their Plants. The Chemists, likewise, long ago informed us, that black Bodies committed to digestion, or reduced to it by Art, grow warm with the same Fire easier than others; different degrees of Heat being required in the head of a Crow, the neck of a Swan, and the tail of a Peacock. And lastly, the Philosophers have confirmed the same by ocular demonstration. If you hold a piece of very white paper in the *Focus* of a burning Glass, it will be a considerable time before it grows hot, and much longer before it takes fire; and when it is just going to kindle, it first loses its whiteness, grows brown, then black, and afterwards flames in an instant. See upon this head the remarkable Observations in the *Memoirs of the Acad. del Cimento*. 266,

Hence, then, we get some light into a good many *Phænomena* of Meteors: for every one knows that there never happens more terrible Thunder and Lightning, than when the face of the Heavens is first obscured with the blackest Clouds, and thickest darkness; whence too, there often suddenly follow prodigious Whirlwinds, occasioned by the rarefaction of the Air from this Heat thus instantly generated, and retained in it.

EXPERIMENT XIV.

Black Bodies do not reflect igneous Light, or Light that gives Heat, though it is impressed upon them by the Sun ever so strongly. This we saw evidently by covering a *Speculum*, which burnt very powerfully, with the thin smoke only of a Candle; for when by this means it was grown black all over, and then directed towards the Sun, an eye placed in the *Focus* perceived neither Light, nor Heat; nor did there appear by any Experiment the least sign of Fire there, though as soon as ever the soot was wiped clean off, and it was restored to its former brightness, it immediately, upon being exposed to the Sun, regained both its shining, and burning faculty. For this reason, eyes that are inflamed are not injured by black Bodies; and when they are affected with a painful Ophthalmia no colour gives them more ease, than darkness does, which is a perfect privation of all. Even *Tschirnhausen's* glasses themselves, if they are thus blacked with the smoke of a candle, do not produce the least Light, or Heat in their *Focus*, though they are directed towards the hottest Sun.

Black Bodies scarcely reflect the Light they receive.

From these Observations, therefore, it evidently appears, how little a matter is often necessary in the Air, to suffocate, and destroy the most powerful effects of Fire, that depend upon the action of the Sun; and how very different a Heat may be suddenly excited in different places from the same cause. And, here certainly, there is nothing more surprizing, than that this should be effected by a black crust, so exceeding thin that the external surface only seems to be concerned in it, without any thickness to assist it.

But, now on the other hand, Bodies that are exceeding white, reflect this igneous Light almost with the same power as they receive it. This is very evident in white Metals, as in the most solid pure Silver, if it is formed into a plain *Speculum*: For that will return the image of the Sun very nearly as vividly as it falls upon it, and for a time hurts and blinds the eyes; and when they are inflamed, and painful it is perfectly intolerable. Look through a plain clear glass towards the Sun, and it seems to transmit the Rays, almost, without any alteration: Let then your eye be placed directly betwixt the glass, and the Sun, and then look in the glass, and you'll scarcely perceive any thing; but if the back part of the glass is covered over with a very white composition of Mercury, and Tin mixed in a certain proportion, the reflexion of the image of the Sun from the *Speculum* will be so strong that the eye will not be able to bear its brightness.

White Bodies reflect it very powerfully.

In like manner every body knows, that the solar Rays reflected by the yellow colour of Gold are vastly refulgent. But this was never more remarkable, than in that instance of a concave *Speculum* in Saxony, which being formed of wood very carefully hollowed into a spherical form, and then polished, and nicely covered over with leaf Gold, burned with an incredible power.

Yellow ones likewise.

And lest any one should imagine that the efficacy of this was owing to the metal-line quality, let him take notice of that other more surprizing one, which too had an exceeding caustic quality, that was made of pieces of yellow straw very accurately fitted together.

In the same manner we may examine the rest.

And thus the red, and all the other capital Colours, so nicely distinguished by the singular penetration of the incomparable *Newton*, may in the same manner be examined, both with regard to the Light that they collect in a *Focus*, and the caustic power they exert there: For if the *Speculums* are made of the same matter, size, and figure, and are polished in the same manner, but are of different colours, then, the difference of the Heat in their *Foci* will give us the doctrine of Colours with regard to their power of generating Fire; and at the same time will shew us what Colours heat, cool, yield a moderate degree of Heat, reflect, retain, and dissipate the Fire that is impressed upon them. But we must hasten to our farther examination of Fire; we can only, therefore, hint at these things at present. Let us see, then, what are the consequences of this Experiment.

COROL. I.

Burning
Speculums.

From what has been observed, the true doctrine of burning *Speculums* may be easily understood, with regard to their efficacy as it depends upon the Colour of their polished surface: For if all other circumstances are alike, a few Experiments carefully made will readily determine the proportion of their focal powers in respect of their Colour.

COROL. 2.

Pigments
heating, or
cooling.

And if we want to know what will be the effect of laying such and such Colours on Bodies with regard to their power of heating, and cooling, we may from the same principles as easily inform ourselves. With respect to the ground that we walk upon, or look at, we know certainly, that black Earth burns the Feet, but is more favourable to the eyes; whereas white scarcely warms the former, but by its bright whiteness dazzles, inflames, and burns the latter. The same thing is easily conceived of pictures, and tapestry. And the knowledge of these things will assist us in a particular manner, in making coverings to secure our Bodies from Heat, and our eyes from the Light. Houses, for instance, that are externally white will be coolest within; and those on the other hand that are black will be hottest; if the walls are made of the same materials, and are of the same thickness. And hats that are very white on their upper surface, and black on the under part of the brim are a vast relief to the Heat when the Sun is exceeding hot.

COROL. 3.

The cause of
Heat in the
Earth, and
Air.

From the same causes the Heat of the ground in some parts of the World grows intolerable, when being very black, it is exposed to a scorching Sun: Whilst in others, the Air is rendered so hot that it cannot be born. This we see particularly in the Island *Ormuz*, where the solar Rays are so strongly reflected from the white mountains that run East and West, and the Air is so excessively heated by them, that the people perish in it, if they don't lie covered in Water all but their heads, which are kept above it by proper supports;

ports; as likewise in *Gamron*, where the same thing happens from a sandy, white mountain, which reflects and collects the Rays in such a manner, that the Heat of the Atmosphere is scarcely any where so violent as it is there: And yet both these places lie beyond the Tropick in north latitude. See *Nieuhof. Itin. Terr. & Mar.* from p. 80 to 91. and other Authors.

C O R O L. 4.

Water, and other Liquors, are raised into the Air by the power of terrestrial and aerial Fire. And the less they are press'd by the weight of the incumbent Atmosphere, the more easily their Particles recede from one another by the same degree of Heat. The higher, therefore, they ascend, the farther they are separated asunder; both on account of their increased Spaces, and their lesser reciprocal attraction. Hence, of consequence, they collect less Fire, grow cooler, and float about through vast Spaces, in form of exceeding fine corpuscles, whose resistance always increases in proportion to their altitudes. And whilst they are thus driven about, the parts of Water may, possibly, be resolved into their ultimate, exceeding hard, immutable Elements, which, tho' very rigid asunder, yet being united together again, may constitute the same soft Body they did before. When by any means now whatsoever, a considerable number of these aqueous Particles are brought into union in this upper, and consequently, colder region of the Air, it is very probable, that the Air is immediately filled with very small icy Bodies; and that these, now they begin to descend, (and thus coming nearer to the Earth, are reduced into smaller Spaces, and hence are more closely united,) by their reflections of the Solar rays, form those Clouds in the Heavens, which to us appear so exceeding white, whose whiteness, the greater it is, the more certainly we can foretell, that we shall soon have Snow, Hail, cold Showers, or cold Winds. But the whiter that side of the Cloud is, that is directed towards the Sun, the colder, of consequence, must the other side be in proportion, as it wants at that time the Solar Heat. Hence it evidently appears, that such Clouds may increase the Heat of the Air in a very short time, especially, if from their different positions with respect to the Sun they should be so situated as to reflect the Solar Rays into one small Space, and thus form a kind of *Focus* in the Air. On the other hand now, if at the same time that the Sun shines, we see exceeding black Clouds in the Sky, there generally very quickly follows Thunder, and Lightning.

Hence Meteors.

C O R O L. 5.

If we rightly understand, therefore, what has been said, we sha'n't wonder at the vicissitudes of Heat and Cold that sometimes happen so suddenly in the same place of the Atmosphere. For if we consider, that as soon as ever the Solar Rays fall directly upon the Air, the Fire, that before tended equally every way, is immediately determined into a Parallelism, we perceive, that on this account the Heat must be much increased. Again, the ground we tread on being thus instantly exposed to these parallel Rays, must of consequence soon grow hot. And lastly, all the Bodies in the Air, or above the Earth, will be affected with the irradiation of the Sun now shining upon them, and therefore must continually grow warmer and warmer. From these causes, therefore, tho' there should not be an addition of one particle of Fire more than there was before,

fore, yet the Heat of any particular place may be considerably augmented. And thus we have now discovered in Nature, another manner of exciting Fire, which before did not appear, and that is, the action of the Sun, thus determining the particles of Fire in a parallel direction.

EXPERIMENT XV.

The collection of Fire parallel in a Focus.

If we conceive, now, certain Corpuscles perfectly white, exceeding smooth, and very small, to be so fitted together, that the Fire, thus render'd parallel by the action of the Sun, and impress'd upon their Surface, may be so reflected, that all the Rays may meet together in a very small point; then, all this incident Fire will be collected in that place, which, had these Corpuscles been situated in the same plane, would have pass'd on in parallel lines, as it fell upon them.

Hence, therefore, the Fire in this place of collection, which for the future we shall call the *Focus*, will purely, from its quantity, be so much more intense than it was before, as this Space where the Rays are thus united, is less than the whole Surface from whence they were reflected. But the force of it was likewise much augmented before, on account of the parallelism already mentioned.

Perfect in a concave Parabola.

Was it possible, therefore, by Art, to construct a concave *Speculum*, whose cavity should be formed by the revolution of the most perfect first *Parabola* of *Appollonius*, and hence would have any exact conoid-parabolical hollow figure; if the matter of it likewise was the densest we are acquainted with, as Gold; and the colour the whitest, as that of the finest Mercury; if it, farther too, like the purest Steel possess'd the most elastic quality; and lastly, if the aperture of its Base was very great: Then, if you placed the circle that terminated the *Basis* of this parabolical Conoid parallel to the apparent Disc of the Sun, all the Fire that enter'd in a parallel direction through this circle, would be collected within the *Speculum*, in a point of the *Axis* $\frac{1}{4}$ of the *Parameter* distant from the *Vertex*: And consequently, by enlarging the capacity of the *Speculum*, this force might be always farther increas'd. But the most industrious Artists have never yet been able to discover such a kind of matter, or to give any hollow Body this exact parabolical figure; and hence, tho' we easily conceive of this efficacious power, yet it has never been reduc'd into practise.

But this could never be formed exactly.

The next thing, therefore, was to try, whether it was not possible to give some exceeding solid, white, hard, and elastic substance a spherical figure, and so to polish it, that there should be no unequal vacuities left in the concave polish'd Surface; and this, it was imagin'd, might be effected by the attrition excited in the action of turning: But this upon trial, was not found so easy to accomplish, by reason of the difficulty of the Polish. The Heat, however, that has been by this means generated, has been found to be so violent, that it almost exceeds all credibility.

The incredible power of Fire in Vilett's Speculum.

Not to mention many others, it is sufficient to take notice of the most perfect one hitherto known; and this is that, which with a good deal of experience and labour, was made by those excellent Artists, the Father, and his two Sons, the *Vilett's* of *Lyons*. This Mirrour is form'd of a metalline substance, nicely compounded, after a great many trials for this purpose, and is of a concave spherical figure, the Chord of the Segment of the Circle, by the revolution

revolution of which it is constructed, or the diameter of the Circle which measures its Aperture, being 43 inches, and consequently, the *Area* of the plane through which the Rays are admitted, $1452 \frac{11}{14}$ French inches. Both the concave and convex side of it is spherical; and both Surfaces are polish'd as nicely as possible. The whole Mass of the *Speculum* weighs 400 French pounds; and lastly, the Rays which fall upon the *Speculum*, through the aperture above-mentioned, when it is directly opposed to the Sun, are collected in the Air, within a circle of half an inch diameter, which is $3 \frac{1}{2}$ feet distant from its *vertex*. Hence, therefore, if all the Rays that come parallel from the Sun, and are receiv'd by the *Speculum*, were reflected into this *Focus*, then the Space they took up in the circle of the aperture of the *Speculum*, would be to the Space into which they are thus contracted in the *Focus*, as 7396, is to 1; and consequently, there would be seven thousand three hundred ninety six times more Fire in this *Focus* than in the Air heated at the same time by the Sun; which is, certainly, a prodigious difference.

We must, however, caution you here, that we suppos'd all the Rays, that fell upon the *Speculum*, to be reflected back again into the *Focus*; but this, by Experiment, is evidently found to be false: For neither is the figure exactly spherical, or is it perfectly polish'd, or without vacuities in its Surface, as the Microscope informs us, and as you may be sure, from looking obliquely at it, for you may see its concave Surface on every side of it. But let that be as it will, if the *Ratio* of the reflected Rays to the incident ones, should ever be discover'd, the proportion may be easily computed: In the mean time, however, this we are sure of, that the Fire, which is generated there, is vastly intense. For by a multitude of repeated Experiments, it evidently appears, that every body, that is combustible by any Fire, will, if it is plac'd in this *Focus*, burn furiously in a moment's time. And even those combustible Bodies, which by reason of their aqueous moisture, won't burn easily, except they are first dry'd by the Fire, will here kindle into a Flame instantaneously. This was evident in a branch of green Wood drawn backwards and forwards through the *Focus*, which flam'd in a moment in every part upon which it fell, tho' the branch was then moist and thick, and did not remain at all in the *Focus*. Within the space of a minute, the six Metals were put in fusion in the same *Focus*; as also, all the Semi-Metals that have hitherto been try'd; even stony and rocky Bodies, are melted and vitrified by it in an instant. And how violent its effect must be, Gentlemen, you may see from this instance, that even Bones themselves, whose Ashes you know, in the cupelling test, so powerfully resist both Fire and Lead, are melted by it in the twinkling of an eye; as are likewise Bricks, Clay, Sand, Crucibles, Marble, Jasper, and Porphyry, which are turned into Glafs. And lastly, the very Stones which the Masons make use of for building the Furnaces design'd for fusing of Iron, and separating it from its vast hard fossil Ore, melt and vitrify in this *Focus* immediately; which no person, let him understand these things ever so well, or let him have seen ever so much of the violence of confined Fires, could ever have imagined; for these same Stones would have remained many years without alteration, in the intense Fire to which these Furnaces are always exposed: So that the power of this focal Fire, is able to effect that in the least instant of time, which the other,

Difficult to
determine a
priori,

But by its ef-
fects, ap-
pears to be
very great.

tho' the strongest we know of besides, could hardly accomplish in the space of some years. And yet this Fire resides in the liquid Air, nay, perhaps, *in vacuo*, the Air being expelled by this vast Heat, and that, without the least *Pabulum* to support it; and it always remains there, so long as the Solar Rays continue to fall upon the *Speculum*.

Some remarkable circumstances in this *Speculum*.

Now the colder the matter is of which the *Speculum* consists, the more intense will be the Heat of the Fire in the *Focus*; and therefore, the denser this metalline substance is, the more powerful will be the effect. But by this coldness, the elasticity is considerably increased, and hence, too, its efficacy will be so much the greater: Whereas on the other hand, as soon as ever the body of the *Speculum* grows warm, its action becomes feebler; and as it gradually grows hotter and hotter, its caustic power is continually diminish'd. Hence, in a very clear, cold, Winter's day, it exerts its force much more powerfully, than in a fine Summer's one. But farther, from what has been already laid down, we know, that the cohesion of the Elements of all Bodies, is constantly weakened by Fire, and that always, in proportion to the degree of it; that hence, the Pores that are left between their Elements are enlarg'd; and that their power of contraction, and of consequence their elasticity, which depends upon it, is hereby weaken'd. Here, therefore, again, is a large field open'd for inquiry; but it is impossible for us to enter into all these things at present. Give me leave, however, on this occasion, to take notice once more, that when this *Speculum* was directed towards the Moon at the full in a clear Winter's night, and the Bulb of a very sensible Thermometer was placed in the center of its *Focus*, there was not the least indication either of Heat or Cold, but the Glass remained exactly at the height it was before, tho' at the same time the *Focus* was so excessive bright, that no-body was able to look at it. And this, upon consideration, seems the more surprizing, because these Rays that thus come from the Moon, were received, by that, from the Sun; and yet we know, by Experiment, that if the image of the Sun is reflected from a very perfect plain glass *Speculum* directly upon *Violettes's*, the Fire generated in its *Focus* will be vastly intense, and near as strong, as if the Solar rays had fallen directly upon it. Hence, therefore, again, is demonstrated a plain difference betwixt Light and Heat, as was before taken notice of. These, now, are the principal physical effects of this *Speculum*, with regard to our present purpose, which I have exactly related, as they are delivered by the worthy Author himself from his own observation, and which will be of service to us presently in treating of the nature of Fire.

Generates no Heat by the help of the Moon.

A very great one by the rays of the Sun reflected upon it by a plain *Speculum*.

Inconveniences of this *Speculum*.

Conveniences.

This noble Instrument, however, has this one inconvenience, that as the Sun must be pretty high to communicate its power to it, and this concave *Speculum* must be so directed to the Sun, that the *Axis* of the lucid Solar Disk, and that of the *Speculum*, must be in the same right line; hence, the Bodies too that are to be examined in its *Focus*, must be in the same line also: For which reason, it is impossible to prevent their falling, when once they come to be melted; and hence, as soon as ever they are put in fusion, they run from the action of the Fire, so that no trial can be made of them farther, which, you easily conceive, would be of the greatest consequence. But this inconvenience is, in some measure, compensated by this property of it, that the external Surface of this polish'd Metal, reflects all the Rays that fall upon it, and hence does

does not much dissipate or change them; whereas your glass *Speculums*, that reflect by means of Mercury incrustated upon the back part of them, must necessarily cause a great dissipation of the Rays, on account of the multiplicity of images that arise from the position of the pellucid Particles of the Glass. And as for the other manner of burning with convex Glasses by refraction, this is still less powerful; for these must reflect a great quantity of the Rays towards every part; and a great many more will be suffocated, and extinguished, whilst they pass obliquely through their substance.

COROL. 1.

From the consideration of what has been now laid down, I think it evidently follows, that the celestial Bodies, as well Planets, as fix'd Stars, make no alteration in our Fire, with regard to Cold or Heat, that we are capable of discerning. For setting aside the Sun, whose effects we have just explain'd, the Moon is the only one of any consequence; but when the image of this is received on this *Speculum*, and reflected into this very small *Focus*, it does not produce the least sign of expansion, or contraction, no, not even in the Air itself. What then can the Light do that comes from the other Planets? Certainly, nothing at all. Nor has the Light of the fix'd Stars any greater effect. If these Bodies, therefore, are endued with a power, by which they are able to act upon the Heat and Cold of our Earth and Atmosphere, which I don't pretend to deny, they must necessarily do it in some other manner, than by the vibration of their lucid Rays. Nor will the Astrologer's referring us to the various Aspects and Conjunctions of the heavenly Bodies, and to the Constellations, make any thing against what we advance; because it always appears by Experiment, that there is no alteration produc'd by any of these causes, in the case we are at present considering. We may venture, therefore, to assert, that all the Heat that flows from the heavenly Luminaries, and is transmitted to us, depends intirely upon the Sun alone, without receiving the least augmentation from any of the rest that has hitherto been discovered.

None of the heavenly Bodies, except the Sun, cause any increase of Fire, either by determining it in a parallelism, or by reflection.

COROL. 2.

These things, then, being well understood, we can't clearly conceive how any considerable alterations can be produc'd in the Bodies of our world by the Stars: For in most of these changes, that we are acquainted with, either Heat or Cold, is concerned, whether new motions are excited, or former ones are altered; but upon Heat and Cold, the Stars have no effect. The influences, therefore, that these heavenly Bodies are supposed to have upon these lower ones, must depend upon some other causes; and consequently, these changes are not owing directly to any communication of Fire, or any alteration of it, that the Stars are capable of producing. Nor in reality, has it hitherto appeared by Experiment, that these superiour Bodies do exert any force upon these lower regions, except what is to be ascribed to the power of Gravity alone; which is vastly different from Light, and Fire, nor has the least dependence upon them. That this power, indeed, on account of the various positions of the heavenly Bodies, must be liable to frequent changes; and hence, from these different degrees of attraction and repulsion, may produce a great many alterations in the Bodies of our world, no-body that is acquainted

Gravity alone seems here to make some alteration.

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with these things will deny ; but at the same time that they have any other power, with respect to us, besides that of Gravity, we never have yet had sufficient evidence to induce us to believe.

COROL. 3.

Surprising
Meteors
from reflect-
ed Light.

These things then being premised, we may again venture from Experiments to account for a great many *Phænomena* that we observe in the Air, which relate to our physical inquiries, which sometimes mightily disturb our chemical operations, and which may be easily understood from what has been said. The famous *Halley* has demonstrated, that there is an incredible quantity of Water perpetually carried up into the Air: That this ascends to the greatest height in very serene weather, appears by the clearness, and increased weight of the Atmosphere at the same time: Nor is it less certain, that it will be there turned into Ice, if its Elements happen to be brought into union in those upper regions. Now what hinders, but that these particles of Ice thus produced, may in like manner be brought together there, and being gradually united into large globular Bodies, may appear in the form of Clouds? And why may not these, from an infinite number of causes, be perpetually changing their figure, be sometimes plain, then spherical, and so of all other figures by turns? Supposing, then, this to be the case, will not the action of the Sun irradiating the Air, and shining upon these *Speculums*, be thence reflected, so as to produce very sudden and surprising appearances of Light? And again, may they not, by being disposed in a different manner, suffocate and extinguish the Rays of Light, and thus in an instant bring on thick Darkness? Whenever the Clouds in the Heavens appear exceeding white from the irradiation of the Sun or Moon, there generally follows very quickly, either Snow, or Hail. And after long drought and fine weather in the hottest part of Summer, I have observed little white Clouds to appear aloft in the Air, which increasing in magnitude very fast, become constantly less white, as they grow bigger and bigger, and a little afterwards, from a large base descending towards the Earth in a pyramidal form, make a perfect shade, and burst into showers with a great violence; the largeness of the drops at the same time evidently shewing, that they were Hail in the upper, colder regions, but suddenly melted as they came down into the lower and warmer ones: Or if the Hail-stones happen to be so big aloft, that they cannot be thus thaw'd in their descent, then they fall to the ground in a solid form, and both ways quickly render the lower Air in the places where they fall, much cooler than it was before. Now these *Phænomena* may be easily accounted for from the simple causes already mentioned: For the higher the particles of Water are raised, the more they will be frozen; and from the greater height they fall, the more violent will be their descent, their celerity being constantly increased in the proportion which *Galileo* has demonstrated. Hence those little Clouds that are seen in *Asia* in very fine weather, and on account of their smallness are compared to an Ox's eye, when they fall from the Sky, come to the ground with a prodigious force, put the Air, that is condensed in that place, in a violent commotion, and thus raise Winds, and Whirlwinds, and sometimes produce Storms that exert their force from a center equally towards every part of the Horizon, their apparent magnitude, during their descent, always increasing in a reciprocal proportion to the squares of their distances.

distances. Does, therefore, the very bright whiteness of the Clouds always depend upon Snow or Ice, that is generated in them? Certainly, Water itself never appears white when irradiated by the Sun, unless it is first form'd into Froth, Snow, or Ice, or receives the Rays and transmits them very obliquely to the eye. But again, suppose this frozen Water to be driven together by the Wind, and to be so collected into one Body, as to reflect the Solar Rays by that part of its Surface that is oppos'd to the Sun; and hence, to heat, rarefy, and put in motion the Air that lies betwixt the Sun and this icy Cloud, whilst at the same time the action of the Light, and Heat, continually varies on every other part of it; suppose farther, the Globe to be large, pretty solid, and not pellucid, and of consequence, the Cold on the part averse to the Sun to be so much the greater, and the Air there so much the denser: From these causes, then, there must necessarily follow an extraordinary rotation of this globular Body, which will be so much the swifter, as the Heat of the Sun is stronger, the density of this icy Globe is greater, the Cold on the hinder part is more intense, and as it falls from a higher very light Air, into a lower one growing gradually denser, and yielding a greater resistance.

I am persuaded, now, Gentlemen, if you will but weigh these few things with attention, you will never wonder at those terrible storms that often happen, when the Weather has been a long time calm and serene; especially, if you consider at the same time, what Attrition, what Heat, nay, what Fire, may be instantly produced, by Bodies falling from aloft through the heavier Air that lies underneath them. These considerations now lead us to take notice of those intolerable Heats that suddenly happen in particular parts of the Earth, and very soon after end in horrible tempests; and which upon reflexion, we shall find to happen generally when the Heavens are full of distinct, scattered Clouds. For if any quantity of snowy, or icy Clouds, especially if they are large ones, are so disposed in the Atmosphere, as to form reflecting *Speculums*, and exert their united force upon one certain place, which you will grant me may be, nay, and often must be the case, pray what must be the consequence? Why, certainly, an incredible Heat will immediately be excited there; the Air will be vastly expanded, so as sometimes to occasion a very large *Vacuum*; about this *Vacuum* thus heated by such a collection of Fire, the expell'd Clouds, and Air, will be agitated in a surprizing manner, and with a great noise; whirling *Vortices* will be hereby produced; and presently after, this *Focus* being destroy'd by a different situation of the Clouds, the Air, Snow, Hail, Water, and whatsoever else is nearest, will rush into these *Vacuums* with prodigious violence. And for my own part, I have long been of opinion, that this reflection of the Solar Rays from icy Clouds, and their being hence collected into large *Foci*, are the principal causes of those terrible *Phænomena*, which frequently happen in so violent a manner, as to make human Nature shudder, and be almost afraid of present destruction. A learned *Englishman* has ingeniously demonstrated with what force the common heavy elastic Air would rush into a perfect *Toricellian Vacuum*, which he proves to be so great, that the celerity of the most rapid Wind, which moves 22 or 23 feet in a second, can by no means be compared with it, as this would run 1305 feet in the same time. *Phil. Trans.* 1686. N. 184. p. 193. Now, only consider, what quantities of these cloudy *Speculums* may be at once produced in the Heavens; and at the same time reflect on

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their

their possible magnitudes, solidities, and situations; and you will easily see, that they may be able to form Spaces of stupendous efficacy, with regard to the Fire that may be generated in them: To which, therefore, Lightning, Thunder, Whirlwinds, Storms, Winds, and the other Meteors, may owe their production. And hence, perhaps, we may understand, why, tho' the Weather is exceeding hot, yet, if the Heavens are serene, and free from Clouds, these things are seldom observed to happen; whereas, when once the Sky grows obscured with Clouds, very extraordinary alterations often immediately follow.

COROL. 4.

Especially
when it
thaws.

But these are never more frequent, or more violent, than when it has been a sharp Frost for a considerable time, and the Earth is grown hard to a pretty great depth. For if it then thaws on a sudden, there generally follows Clouds, uncommon Heats, Thunder, and Lightning: And the reason seems to be this: All the Vapours, and pinguious Exhalations, that in warm Weather arise from the Earth, were, during that time, lock'd up within this hard crust, and there agitated by a subterraneous Heat; which appears evident from hence, that if in the hardest Frost, you break the Ice in the ditches, there immediately exhale from them warm Vapours, the quantity and warmth of which are so much the greater, as the Frost is harder, and the Ice thicker. Now as soon as ever the upper frozen Glebe comes to be resolved by the warmth, these Fumes that were thus confined, instantly disengage themselves, and being carried up into the Air, form smaller, and then larger Clouds, which being afterwards roll'd up together, and irradiated by the Sun, very soon bring on the *Phænomena* we have mentioned. Hence, in *Russia*, *Sweden*, and *Denmark*, such excessive Thunders generally follow a thaw. It might be added too, that the Particles that were exceedingly consolidated by the Cold, do still excite a very great motion of attrition.

COROL. 5.

The Heat
peculiar to a-
ny place,
whence?

But let us consider farther, that the reflexion of the Solar Rays from the ground, buildings, and mountains, may be the occasion that some particular places, in the same position to the Sun, may be much hotter than others. For it is easy to conceive, how all these things may either accidentally, or on purpose, be so disposed as to make a very great alteration in the Heat in the center of the place. And then besides, the diversity of the colours of the Bodies round about, may, as has been before observed, very much increase the force of this Heat. But we ought particularly to remember, that in different seasons of the year, the direction of the rays of the Sun upon these Bodies, is continually changing in a very remarkable manner, and hence the reflexion of them, and the Heat of their *Focus*, will be increased, diminished, and perpetually varied. From these principles then, we may easily understand, how it comes to pass, that some places at certain times of the day, or year, are so different from themselves with regard to their Heat, Colour, and Light, (as it is a common observation, that some places are hottest with the morning Sun, and others with the afternoon) for we have nothing to do but to have recourse to the three circumstances just mentioned, and examine them with regard to the places under consideration. And it will then appear, which
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is much to our present purpose, that a greater or less degree of Fire, may be produced in any particular place, without any other cause than mere reflexion, and the collection, and dispersion of Rays that depend upon it. People generally imagine, that, *cæteris paribus*, the Heat is greatest in places that are levellest and most open; but the contrary is always observed to be true: For in calm, dry, hot Weather, the Air on large plains is always more temperate, and refreshing; that in the vallies, more sultry and troublesome. And hence it comes to pass, that Horses, and other Cattle, are brisk, and run on the plain heaths without being tired, or losing their Wind; whilst, at the same time, they grow languid with the heat in other places. And the reason is evident; for in these level places, there is no Heat but what is owing to the direct rays of the Sun, or the reflexion of them from the Clouds alone. These observations, now, are of great service in helping us to form a right notion of Fire, which, otherwise, is falsely imagined to be peculiar to some particular parts of the Earth; to account for which, many extraordinary causes have been mentioned very different from the true nature of Fire. If we examine this affair, however, in a proper manner, it will always appear, that Fire considered absolutely in itself, is equally diffused through all Bodies, and every part of Space.

COROL. 6.

And here let me observe, in one word, before I quit this subject, that the Meteors in the Air, the Heat on the Earth, and the Effects that are thence produced, owe their origin, degrees, changes, and effects, principally, to the various reflexions of the parallel rays of the Sun.

Conclusion concerning Meteors.

COROL. 7.

But it is a matter of vastly nicer inquiry, and would be of extraordinary service, could human industry and penetration ever arrive at it, to determine the true proportion between the quantity of Light falling upon a reflecting Body from a given Space, and the same when it is collected in the *Focus* after reflexion. Suppose, for instance, the Light contain'd in a circle of 2 feet diameter, to fall upon a concave spherical *Speculum*, and to be thence reflected into a circular *Focus* of an inch diameter; we can then easily, by the help of Geometry, find the proportion of the *Area* of this lucid Circle, to that of the collecting *Focus*, since these are to one another, as the squares of their diameters; and hence the Mathematicians presently infer, that the incident Light is to the reflected, in the same *Ratio*. But whoever examines this affair as a Philosopher, will find much greater difficulties in resolving this problem, than he is at first aware of.

The proportion of the Fire collected in a catoptrical *Focus*, difficult to determine.

For in the first place, Gentlemen, how will you be able to determine the proportion of the vacuities or pores in the concave Surface of this *Speculum*, to the solid parts of it that cause this reflexion? Every thing that has been hitherto made use of for this purpose, has been considerably lighter than Iron, and consequently, much more porous than Gold; but the solidity even of this, with respect to its magnitude, has never yet been discovered. Hence, therefore, we see, that it is impossible to settle this first circumstance; and yet this is absolutely necessary to the satisfying our present inquiry. Perhaps only a thousandth part

First, as we don't know the true solid part of the *Speculum*,

part of the bulk of this Body is perfectly solid and impenetrable ; the rest, with regard to the matter of which the Body consists, intirely vacuity or pores. How great a quantity of the incident Light then must necessarily be lost ?

Nor the exact figure.

But suppose now, which is however by no means the case, that the matter was absolutely solid, by what method will you determine the figure of the *Speculum* ? You imagine, for instance, it is spherical. How do you know it is so ? Certainly, if it was perfectly so, its concave Surface would then appear black, except to an eye placed in the *Focus*, or in the lucid vertical Cone produced from the *Focus*, or a little on the sides, on account of the diverging coloured Rays, according to the elegant doctrine of the incomparable *Newton* ; Whereas we find, on the contrary, that its bottom may be seen in every oblique position. But if this don't satisfy you, and you still fancy such an exact polish may be given to Metals, take a concave *Speculum* that is looked upon to be finished in the nicest manner, and examine it with one of the best Microscopes ; and you will soon see how rough, unequal, and porous that Surface is, which you imagined so smooth and equable ; and will be forced to confess, that there is but a very small part of this Surface that is similar, but that the figure is every where perfectly irregular. How, then, can any person think it possible to determine the quantity of the reflected Light from the figure of the *Speculum* ?

Nor the homogeneity of the matter.

But again, supposing we could get clear of these difficulties, there is another as considerable still behind : For we must be certain, whether the matter of this caustic *Speculum* is every where perfectly homogeneous, and has, in every point of its Surface, the same power of equably reflecting the rays of Light ; since it appears by the *Newtonian* doctrine, that in this respect too, there is a vast deal of difference in different Bodies. It evidently appears, therefore, that we can come to no certainty in this inquiry, till this is likewise determined. It is possible, for instance, that, in the substance of which the *Speculum* is composed, there may be some matter that we are not at present acquainted with, which may have no power of reflexion at all, and which, consequently, will suffocate and extinguish the incident lucid Fire, in proportion to the quantity of it that is contained in the reflecting Surface. But, now, tho' we could in these three respects certainly demonstrate the proportion of the power of the Fire in the *Focus*, to that of the parallel Fire that fell upon the *Speculum* ; yet this will regard only the efficacy of it, as it depends upon the quantity.

Fourthly, because the force of Fire don't depend entirely upon its quantity.

But hence, we shall never be able justly to determine, what proportion the virtue of this focal Fire bears to the same, when it was directed by the Sun through the Circle that measures the aperture of the *Speculum*, and that, for the following reason. We are not certain, whether the *impetus* of Fire is always proportionable to the number of Particles contained within the same Space ; and consequently, whether this rule will always hold good, that a double quantity of Fire constantly exerts itself upon Bodies with a double Force ; for notwithstanding this is generally taken for granted, yet there is a great deal of room to dispute it : And tho' it is certain, that a larger quantity of Fire in a smaller Space, will always be more efficacious ; yet, it still remains matter of doubt, whether its active power receives no augmentation, except purely from its quantity.

This suspicion is grounded upon the following observation. It is evident from

from Experiment, that there are certain Bodies in nature, which whilst they are separate produce no effects, but as soon as ever they approach one another within a determinate distance, immediately excite new motions which did not before exist, which grow continually greater the nearer they come to one another, and cease again in an instant, when they are removed so far asunder, that their reciprocal vertue can exert itself no longer. For an instance of this, let us take two very good Loadstones: Let one of these be at rest in any particular place, and it will always of itself continue so: Bring, then, another gradually towards it, and you will find by gently proceeding the most distant point in which this latter will be able to put in motion, and agitate the former; and as you successively bring it nearer and nearer, the motion of them both will become more remarkable, the power that generates it always increasing as the distance between them grows less, though in a proportion that is not yet determined. The great *Newton*, indeed, for very weighty reasons suspected it to nearly in a reciprocal triplicate *ratio* of the distances.

As appears
by an in-
stance in
other Bodies.

For the discovering of this the famous *John Muschembroek*, Professor in the *Academy of Utrecht*, has taken a vast deal of pains, and that with very good success. Let us suppose a number of Loadstones equally powerful to be suspended so as to be in the same a spherical surface, and so near one another as to be just ready to feel each other's reciprocal attraction: Let us then imagine them all to be brought very gently towards the Center of the Sphere, and consequently nearer to one another. Would not they then, if there was a hundred of them, be all put immediately into a surprizing motion? Suppose again, that at a certain distance they were all perfectly at rest; and then conceive one Loadstone situated in the Center of the Sphere: certainly, in that very instant of time there would arise a very extraordinary motion in all the others together, not one of them keeping their position, though they were all absolutely quiet before. And when these, again, began to come towards the Center, the motion would grow greater at every distance, and be very different from what it was just before; since the action produced between the attracting, and repelling Poles, would continually vary in every point of approach. The same thing might be demonstrated in the Air, and a great many other Bodies, but this Example is sufficient. Supposing, now, such a power as this, or perhaps a greater, to be implanted in the Elements of Fire; it will, then, be possible, that the force, which they scarcely had at all when asunder, may be exceedingly increased when they are collected together; and hence the Fire in the *Focus* may be vastly more intense on account of the nearness of its particles, than of their number. And, indeed, the truth of this doctrine has been a good while certainly confirmed by the following Observation. If the Thermometer, in an open place, irradiated by the Sun at noon in a cold Winter's day, stands at the degree 20; and at the same time your furnace stones instantly melt, and vitrify in the *Focus* of *Vilett's Speculum*; what do you imagine would be the consequence, should the Thermometer be placed in the *Axis* of the *Speculum* five inches distant from the *Focus*? In all probability you would expect some extraordinary effect; and yet by Experiment we find that there is scarcely a Heat there of 190 degrees. Does it not, then, hence appear evident, that this vast difference of Heat cannot arise from condensation alone, but that there must likewise some new agitation be excited in the particles themselves

And in Fire
itself.

selves from the nearness of contact? But since we have made it clear, from what has formerly been laid down, that it is the peculiar property of Fire to expand both itself, and all the Bodies it acts upon; it is possible, that this quality may be vastly increased by this collection of the particles of Fire into one place: And hence, perhaps, its caustic power may in a moment be so prodigiously augmented.

Lastly, because we don't know the efficacy of the curvature in different parts of the *Speculum*.

But lastly, we are not yet certain whether the power by which the parts of the *Speculum* reflect these igneous Rays, is as great about the *Axis*, to which the Rays fall parallel, as it is in the other parts of the surface that are more distant; and hence, till this is ascertained, we may fairly doubt, whether all the Rays reflected from the *Speculum*, and collected in the *Focus*, meet there with so equal a force, that we may venture to assert, that the Fire excited there is proportionable to the number of the united Rays.

COROL. 8.

A method of determining this Fire.

I have taken a great deal of pains to discover, if possible, a method by which we might determine something certain in this point: And at last it appeared, that if any part of the *Speculum* is covered with an opaque black Body, the Rays from all the other parts of the *Speculum* that are open, will nevertheless, be constantly collected in the *Focus* without any aberration; nor does it at all signify which part of the concave is covered. If we conceive, now, the whole aperture to be covered with a circular brass plate; then nothing will be received, nor any thing reflected. But as we can divide this Circle from the Center into as many equal parts as we please, we may by this means exclude, or admit, what quantity we have a mind of the rays that fall upon this circular *Area*. And, hence, the proportion of the admitted Rays, to the whole that were before received upon this plate, we can determine at pleasure. Thus, therefore, we can collect in the *Focus*, half, a third, a thousandth, or any other part of the Rays; and then, by comparing the degrees of Heat produced in the *Focus* by these different quantities, may be able to discover, whether the force of the Fire thus generated, is always in proportion to the number of Rays united in the *Focus*, or depends upon some other law. By this method, then, all the Rays of Light that fall upon the whole aperture of *Viletti's Speculum* may be divided in any *Ratio*, in which we can geometrically divide a circle; and the efficacy of the Fires they excite in every proportion may be thus examined.

COROL. 9.

In order to determine its power.

If by proper Experiments, therefore, it was known, what part of this brass circular plate must be open to admit just Rays enough to make Water boil when placed in the *Focus*; and this aperture should afterwards be very gradually enlarged till the focal Fire would raise the Mercury in the Barometer to the degree 424: Then, this degree of Heat would be double the former, as far as it discovers itself by this dilatation of the Mercury. We might, then, examine the proportion of this last aperture to the former, which produced only half as much Heat; and, hence, by comparing the *Area* of these apertures thus discovered, and the effects of the caustic powers we observed from each of them, we might at last be able to determine, how much of this force depends

pend upon the quantity of the Rays, and how much on this coarctation of them into a smaller space, and the reduction of the Elements of Fire into a nearer union. And this, as it would be of very great service in furnishing us with proper materials for a History of Fire, it seems plainly to demonstrate that the intenseness of this Fire, is not owing only to the number of the Rays, but to their proximity likewise, by which the force of the particles of Fire is continually increased: A few Experiments, at least, that have been made with this view with concave glass *Speculums* induce us to be intirely of this opinion. Thus, then, we have sufficiently explained the greatest force of Fire that has ever yet been discovered; which, in very cold weather, is produced in one simple manner by that quantity of solar Rays that pass through a Circle of three feet seven inches diameter. Had these Rays, now, proceeded on without meeting with any obstacle, they would have excited but a small degree of Heat in the Air; and if they had constantly kept on in the same direction through an Air growing gradually finer and finer, the Heat caused by them would have grown less and less by degrees, till at last perhaps it would have been diminished to a greater degree of Cold than was ever yet discovered. Hence, then, we see plainly what wrong notions persons generally have of the nature, and action of Fire; since it evidently appears, that the difference betwixt the intensest Heat that we are hitherto acquainted with, and the extreme Cold, is caused purely by the action of a resisting Body. And, hence again, we may almost venture to infer, as we did before, that Fire is equally diffused through all Bodies, and every part of space; and that its activity does not appear, except when it meets with some resistance. As, the aperture, now, of the *Speculum* we have been treating of may be constantly increased; hence, the strength of the focal Fire may be augmented *in infinitum*.

COROL. 10.

No body has ever yet discovered a stronger Fire in any place, than that which is collected by *Vilett's Speculum*; for that which is generated by *Tschirnhausen's* burning glasses is not so great. Hence, the effect of the greatest Fire that we know of, is the turning Flint into Glass in a moment, in *Vilett's Focus*. A greater effect than this has never yet been observed; for though Lightning has sometimes instantly melted Iron, yet it never has, to my knowledge, vitrified either Stones, or Metals. The vast violence, therefore, of the Fire in this *Focus* we cannot consider without wonder, and astonishment: And yet I assert, that this very same effect of vitrification, may be at once produced in the coldest places, and by the coldest Bodies, without the assistance of any Sun, Light, *Focus*, or combustible matter; and, hence, that the ultimate effect of the most intense Fire is always and every where producible, even in the darkest and coldest parts of space. And this is evident; for if in the sharpest Winter-night, you strike a choice Flint against a piece of well tempered Steel, you may by that means always procure exceeding lucid, vivid sparks, which make a whizzing noise as they fly through the Air. Now if you catch the Corpuscles thus struck off, upon a clean paper underneath, you will find them to be glass Spherules, composed either of the melted Flint, or Steel, or both together, and formed into this figure by their rotation through the Air. Hence, therefore, we are certain, that the force of the Fire generated here,

Attrition
produces the
effect of the
greatest Fire.

U

must

must have been strong enough to have reduced these exceeding hard Corpuscles to such a fluid state, that they might by this equable rotation through the soft Air be reduced into these spherical Bodies, which, upon examination, we find to be perfectly of a glassy nature. But the turning Stones and Metals into Glass, is almost the greatest and ultimate effect of the strongest Fire; so that hence it appears, that the action of this momentaneous percussion is as efficacious, as that of the most violent caustic *Speculum*. If a prodigious large choice Flint, therefore, should be struck against an exceeding great Body of Steel, what a Fire might be instantly produced? Thus, then, I have explained a second method by which the greatest degree of Fire may be readily generated; viz. by collecting the parallel Rays of the Sun into a very small point by reflexion.

EXPERIMENT XVI.

The pro-
duction of
Fire dioptri-
cally.

If the same Fire, thus determined into a Parallelism by the Sun, falls upon a very pellucid glass, nicely polished, and perfectly spherical, it will be collected in a *Focus* that burns very violently.

The truth of this has a long time been discovered; but it never appeared more accurately than by the glasses of Mr. *Tschirnhausen* in the possession of the Duke of Orleans, which were made use of in the Palace Garden on purpose to try some Experiments concerning the nature of Fire. An historical account, therefore, of this affair can't here be omitted; as it will give us a considerable light into the properties of Fire, the effects produced by these glasses being the greatest that were ever produced by any of the same kind. See *Mem. de l'Ac. Roy des. Sc.* 1699, 90, 1700, 128. 1702. 34.

The greatest
known.

The biggest glass is of a circular figure, four feet in diameter, and convex on both sides; and if it is directly opposed to the Sun in the summer time betwixt nine in the morning and three in the afternoon, when the Air is clear, and freed from its Water by preceding Rains, it produces a *Focus* at twelve feet distance from the glass, whose Diameter is an inch and a half. This is what Mr. *Tschirnhausen* made use of himself.

If combustible Bodies are placed in this *Focus* they take fire immediately; Lead is soon melted; and Bricks are vitrified, if they continue there a good while. Now from these effects compared with those of *Vilett's Speculum* we may draw the following Corollaries.

COROL. I.

The catop-
trical, and
dioptrical
Fire com-
pared.

The Diameter of the circular aperture of *Vilett's Speculum* is 43 inches; hence, the circumference, $\frac{242}{7}$ inches. The Diameter of the Circle of *Tschirnhausen's* Convex, is 48 inches; its circumference, therefore, $\frac{1514}{7}$ inches: Consequently, the quantity of the incident Rays upon the Circle of *Tschirnhausen's* glass, is to the same upon *Vilett's Speculum*, as 2304. to 1849; and yet the action of *Vilett's Speculum* is much quicker, and a great deal more violent, than that of this glass *Lens* of *Tschirnhausen*.

COROL. 2.

The catop-
trical more
powerful,

Hence it appears evident, that Catoptrics rightly improved is better suited to give us the incident Rays in their full force by reflexion, than Dioptrics, with the utmost advantages, is by refraction; and, therefore, that a great many Rays are lost when we endeavour to collect them by diaphanous burning glasses.

COROL. 3.

But how great now, likewise, is the difference of their *Foci*? The *Area* of the circular aperture of *Vilett's Speculum* is $42\frac{1}{8}$ square inches; its *Focus* $7\frac{1}{2}$ square lines. The *Area* of the Circle of *Tschirnhausen's Lens* is $10\frac{1}{8}$ square inches, the *Focus* of it, $2\frac{1}{2}$ square lines: And, therefore, the *Focus* of the *Speculum* is to the *Focus* of the *Lens*, as 1, is to 9; whence it appears, again, that the method of generating Fire by reflexion, is more powerful than by refraction. This caustic power, therefore, may be carried to a greater height by opaque *Speculums* than by transparent *Lens's*: For an orbicular *Lens* of four feet diameter, is almost the greatest that the Workers in Glass could ever yet make, on account of the construction of their Furnaces; whereas the formation of *Speculums* is not as yet, perhaps, arrived to its greatest perfection; though we have no very great reason, indeed, to expect otherwise. For who, that judges justly of things, don't reflect with some regret, that no Prince should think it worth while to reward the industry of these consummate Artists in a handsome manner, and encourage them to farther Improvements? But this is the hard fate, that the most beautiful Arts are frequently exposed to.

Because it
unites the
Rays more
closely.

EXPERIMENT XVII.

The noble *Tschirnhausen*, however, not being satisfied with the preceding Experiment, began to think of contracting the former *Focus* into a narrower compass, and by this closer union of the Rays rendering its caustic power more intense. For this purpose, therefore, he made use of a smaller glass *Lens*, the Segment of a lesser Sphere, which being placed directly parallel to the former, received all the Rays that were collected by that larger one, and were proceeding on to its *Focus*, and contracted them into a circular space of only eight lines diameter; and consequently, by this new contraction, reduced these Rays from an *Area* of 81 lines square, to one of 16. But though by this method he brought them into a nearer union; yet he lost a great many Rays by this second refraction; though this, however, did not hinder but that the caustic power of this latter *Focus*, was stronger than the former. And this was the ultimate effect of the skill of the celebrated *Tschirnhausen*. Thus then, Gentlemen, I have endeavoured to explain to you as fairly and clearly as possibly, the most efficacious methods, hitherto discovered, of generating Fire by the assistance, both of the catoptrical, and dioptrical Science. I imagine, however, that you'll expect as Chemists, that I should lay before you the surprising alterations that Bodies undergo when they are exposed to the power of these Glasses, for producing of which, you will perceive there is no need of any gross Fire, though these effects are much greater than ever were brought about by the most violent Glass-house, Docimastic, or Metallurgic Furnaces. Nor let any one take it amiss, that I relate here those things, that may be found in the *Memoirs* of the Academy of Sciences: These Books are not in every body's hands, and I am at present professedly treating of Fire. The chief, then, are as follow.

The greatest
dioptrical
Fire.

1. Moist boughs of green trees, or wood soaked in Water, held in this *Focus*, take fire in a moment, and consume in Flame, Smoke, and Ashes.

The principle effects of
such a Fire.

U 2

2. Water

2. Water contained in a small vessel, begins to boil in this *Focus* immediately. And I wish it had been tried by *Fahrenheit's* mercurial Thermometer, whether whilst it boiled in that place it was hotter than usual; that thus we might have seen whether the intense force of this focal Fire, could communicate to boiling Water a greater degree of Heat, than any other Fires, in all which it is constantly observed to grow equally hot.

3. Thin plates of Metal placed in this *Focus*, do not melt immediately, but gradually, after they are heated to a certain degree. And if they are so thick, that the force of the Fire can't penetrate quite through the plate, they won't very easily be melted at all.

4. Bricks burnt, or dried in the Sun, *Talc* itself, and other Bodies, grow red in a moment, and soon after run into Glass.

5. Sulphur, Pitch, and Resin are melted though they lie under Water.

6. A thin piece of wood covered with Water, and exposed to the strongest *Focus* a good while in summer time, seems perfectly intire if you look on the outward parts of it, but if you break it, it appears burnt within, and turned to a coal. Now this very extraordinary *Phænomenon* seems to me evidently to indicate, that this intense Fire cannot heat Water beyond a certain degree; which being less than that which will set fire to wood, it prevents the *Focus* from burning the wood in those parts that are contiguous to the Water.

7. If the substance to be examined is fixed upon a very black Body, the power of the *Focus* is vastly increased.

8. If Metals, or other Bodies, are laid upon charcoal made of green wood, and not thoroughly dried, they will be melted in the twinkling of an eye, throw out sparks, and fly off. Lead, and Tin, melt soonest of all, fume, calcine, vitrify, and disappear.

9. The Ashes of all kinds of vegetable are turned to Glass immediately.

10. If a pretty large Mass is exposed to this *Focus*, it frequently happens, that this Fire won't put it in fusion; but if you reduce the same to Powder, it generally melts pretty easily: If it should still, however, obstinately resist fusion, it may readily be effected by mixing of some sorts of Salt with it.

11. All Bodies, that are black, and continue so in this *Focus*, suffer the greatest alterations there: Those that are white when they are put into it, and afterwards grow black there, are chang'd with more difficulty, and not under a longer time: Those that are black when they are exposed to this *Focus*, and afterwards grow white in it, resist its force still much more powerfully, especially if they become white after they are put in fusion: But those that continue perfectly white in this intense Heat, undergo the least alteration of all; as Lime, *English* Chalk, and Flint.

12. All Metals plac'd in this *Focus*, in a *China* vessel that is not glaz'd, vitrify immediately, if you take care to heat the vessel leisurely, that the sudden force of the Fire don't break it, and it is itself so thick, that it won't be melted.

13. If the matter to be examin'd by this Fire is placed in a large glass *Matras*, and the *Focus* is so carefully directed, that it shall affect this matter, but not the Glass through which it passes, then the *Phænomena* that are produced upon this matter within the Glass, will be very surprizing.

14. Nitre contained in such a vessel, and acted upon by this Fire, grows perfectly volatile in the least instant of time, and then is intirely changed into

a volatile Spirit of Nitre. This effect now is so much the more wonderful, because Nitre, when it is melted by other Fires, scarcely undergoes any alteration, but runs just like Water; and before it can be reduced by Fire into a Spirit, it always requires a mixture of some earthy Body with it, or an addition of true Oil of Vitriol, or its *Calx*, in which there still remains some portion of Oil: Here we see the same thing effected without any mixture at all.

15. The light of the brightest full Moon being collected by this Glass, gives an exceeding lucid *Focus*, but not the least indication of Heat.

16. It moves, agitates, and drives about almost all Bodies, even in *vacuo* itself, tho' sometimes not without exceeding great danger.

From these Experiments, then, and a great many more, it appears, that this *Focus* of *Tschirnhausen* is weaker than *Vilette's*, but that, nevertheless, it is much better suited to the examination of Fire by its effects.

COROL. I.

If Water, or pieces of Ice in the Atmosphere, should by any physical causes be so roll'd up into a globular Cloud, as to form a pellucid Sphere, tho' its figure continued ever so short a time; then, this being irradiated by the Sun, might in an instant produce a *Focus* much more violent than *Tschirnhausen's*; which would be at the distance of a semi-diameter of the Sphere on that side averse to the Sun: The Air, therefore, would be there vastly rarified, and hence, again, must arise very sudden and surprizing *Phænomena*. For whoever considers the perfect transparency of Water raised into the upper regions, and reflects at the same time on the vast quantity that often falls in showers in a very short time, will easily understand from Dioptrics, what must be the consequence, should it be formed into a very large Sphere. If we imagine, again, the Rays thus falling upon such a Sphere to pass through it, and by this means to cause a vast Light and Fire, behind the Sphere, in a line that passes through its center and that of the Sun; whilst at the same time there appears nothing but thick darkness on that part that the Sun shines upon: Perhaps, it will not seem improbable that this is the case, when some parts of the Heavens appear terrible black, and soon after break out into prodigious Thunder and Lightning. But this spherical figure of these Clouds will in a particular manner produce a very considerable difference in the Light and Heat of the Spaces intercepted betwixt these Spheres and that of the Spheres themselves: Hence, therefore, very sudden and extraordinary appearances must arise one moment, and vanish again the next, from these swift changes that happen in the Air; which in some places will be rarefied and ignited, whilst in others, at the same instant, it is condensed and refrigerated. But these hints are sufficient; if you'll carefully attend to the *Phænomena* of Meteors, by means of this principle, of yourselves, you will easily understand them.

COROL. 2.

On this occasion, Gentlemen, I can't help reminding you again of what I have taken notice of elsewhere, *viz.* that Metals vitrify much sooner, and more intimately by the sole attrition produced by striking Flint against Steel, than by this double Dioptrical *Focus*, which is the strongest of this kind, that we are acquainted with. The truth of this is evident: For *Vilette's Focus* is much more powerful

Dioptrical
Fire in the
Air.

Fire greater,
and more
readily ex-
cited by at-
trition than
Dioptrical
Glasses.

powerful than *Tschirnhausen's*; and yet iron is sooner turn'd into Glafs by percussio, than it is even by that. Hence, therefore, we see plainly, that the power of attrition in elastic Solids is vastly great.

COROL. 3.

No need of
any matter
from the Sun
to the most
intense Fire.

And hence, I infer, that there is no need of any action of the Sun, that we are at present acquainted with, to produce the strongest Fire, that has ever discovered itself by the quickest and most powerful effect; nor is there any inflammable matter necessary to put into fusion, intimately, and in an instant, that Metal, which, of all others, is melted with the greatest difficulty, especially, if when the Experiment is made, it is exceeding cold, and in a very cold place: Nor for this purpose do we stand in need of any melting Furnace, or so much as a vessel to contain it. All which paradoxes are plainly confirmed by this common way of striking Fire.

COROL. 4.

Perhaps the
Sun does not
emit such
Fire.

I have been a great while in doubt, whether I should venture to publish an opinion; which I have long revolved over and over in my own mind; in dependance, however, upon your candour, I'll take the liberty to do it. It seems probable then, that the Sun does not in reality emit any igneous matter, to which we can ascribe any of the actions of Fire that fall under our observation; but that it has only a power of determining the pre-existent Fire into parallel right lines, without making the least addition: And hence, that the very same quantity of Fire being, after it has obtained this direction, collected, either by reflexion, or refraction, produces all the effects by this union of the Rays that were before dispersed, and the new power which they gain in consequence of it. But before I proceed, give me leave, by an easy Example, to illustrate this affair, which it is possible, to persons that are prejudiced against this opinion, may appear something obscure. Let us take, then, a hollow brass Cube, whose sides are three feet square; three of which suppose close, and the other open: Let the open side of this Cube be turned directly to the Sun, but be covered with a white paper; and in its cavity let there be placed one of *Fahrenheit's* Thermometers, made with Spirit that's very easily affected with the least degree of Heat. So long, then, as the Paper hinders the Sun from shining into the Cube, so long will there be a great degree of Cold there, if the season at that time is very cold. Let the Paper, now, be at once taken away, and that very moment the whole cavity of the Cube will be irradiated by the Sun, and the measure of the increased Heat will be determined by the Thermometer that's fix'd there. The Philosophers now assert, that the Fire that produces this new Heat, is emitted from the Body of the Sun with an inconceivable velocity. On the other hand, it seems probable to me, that the Sun does no more now, than it did before, and indeed, than it always does, and that is, it determines what we call Fire into right lines, when it meets with no opaque Body to intercept its power: And hence, that the Fire in this Cube remains exactly the same that it was before, and has only received a new rectilinear direction towards that side of the Cube that is opposite to the open one; whereas the Fire, whilst the Cavity was cover'd with the Paper, exerted its force equally upon all fix. In this manner, then, I imagine the Sun equably heats this whole Space, this side in particular, and

and causes this difference in the Thermomer, purely by this determination, without the least addition of any new matter. But again, suppose *Vilette's Speculum* to be directed to the meridian Sun, but to be cover'd with a very white linnen Cloth; then, there will be no more Fire or Heat in the Cavity betwixt this covering and the *Speculum*, than there is any where else. Now remove this Vail, and in an instant the Fire that was in the cavity of the *Speculum*, and tended every way equally, is driven in parallel lines upon its concave Surface, and thence being reflected into the *Focus*, produces a most violent Fire there, which, in reality, did not proceed from the Sun: Nor is there, indeed, either more or less Fire than before, but only it is determined in a different manner. In a refracting *Lens* too the case is exactly the same. Hence, then, neither the Fire excited by attrition, or produced by this *Speculum*, or *Lens*, would upon this supposition depend at all upon the Sun with regard to its matter.

COROL. 5.

What now is the greatest degree of Fire that human skill, and industry, can at present produce? Why, from what has been laid down, it plainly appears, that it would be in that place where the *Focus* of *Vilette*, and the strongest of *Tschirnhausen* should be made to meet together in an opposite direction, and coincide. For since the *Focus* of the *Speculum* is in the open Air, and in a point of its *Axis* three feet and a half distant from its *Vertex*; hence, this *Apparatus* of *Tschirnhausen* may be so placed between the *Speculum* and the Sun, in the *Axis* of both of them, that this dioptrical *Focus* shall exactly unite with the former catoptrical one, and that without at all preventing the Solar Rays from falling upon the *Speculum*. In this place of concurrence then will be found the most intense Fire, that human art at present is capable of exciting. I confess, indeed, that the force of this vast Fire can't conveniently be directed upon any Bodies placed in the *Focus*, for more than a moment; since as soon as ever they are melted, they will drop out of it: The greatest possible Fire, however, is thus determined. If, then, it is no ways repugnant to nature, that the globular and concave Clouds of Ice may have their *Foci* united together in the manner just mentioned, what prodigious effects may thence be produced?

A physical manner of producing the greatest Fire.

COROL. 6.

Suppose, now, this greatest Fire to be really excited in the place described; it will then continue there so long as the *Axis* of the Sun, dioptrical Glasses, and *Speculum*, remain in the same right line, and the distance between the *Speculum* and the Glasses is not altered. And, hence, if these instruments could be kept in the same situation, and at the same time be contrived to move in such a manner, as to be always directly opposed to the Sun; then this immense Fire might, in a clear Summer's day, be kept up from nine o'clock in the morning to three in the afternoon; nor would it, during all that time, want the least *Pabulum* to support it, but would persist in the same manner as it was produced. Thus, then, we form an *Idea* of the greatest Fire, very different from what any body ever had before: For from the laws of Nature thus discovered, we see it is possible that Fire and Light, of a determined power and magnitude, may exist, and continue in any place of the universe without the least *Pabulum* to sustain it.

Which continues a great while without any *Pabulum*.

COROL.

COROL. 7.

And instantly acts with vast force.

And what is principally surprizing in this Fire, is this, that the very instant that its cause begins to act, it immediately exerts itself with its full force, and with as great a degree of violence, as it ever acquires afterwards: Except, perhaps, you may look upon it as still more wonderful, that upon covering the *Speculum*, there don't remain in the *Focus* the least physical signs of that Fire which existed there, and acted with immense power but the moment before; nay, on the contrary, the Light, Heat, expulsion of the Air, and every other effect, disappear at once, without leaving any marks behind. Who could have believed these things? May, therefore, the brightest Light, and the strongest Fire in the Universe, be generated, and destroy'd again, in an instant? But the Fire now in the *Focus* thus described is not visibly bright, except in the *Axis* of the Sun and the *Speculum*; on the sides there is no Light to be seen at all; and, hence, it gives no indication of its presence by any lucid appearance, except to an eye placed in this *Axis*, where the immense brightness confounds and destroys the sight in a moment.

COROL. 8.

A new position concerning the nature of Fire.

Now, whilst I examine these things carefully, I think I discover a farther confirmation of that surprizing physical property of Fire, by which when it is left to itself, it constantly, like the *Radii* of a Sphere, expands and diffuses itself uniformly and equably from the center of its magnitude. Since, therefore, this Fire exists every where alike, its power, of consequence, will be every where in *equilibrio*, and, hence, will so long produce no sensible effects; but as soon as ever this *equilibrium* is by any means destroy'd, then, immediately it may appear by its operation to be infinitely powerful. In which cases, perhaps, we shall be mistaken, if we imagine, that any new fire is produced, or that there is any increase in the power of that which existed before.

EXPERIMENT XVIII.

Fire may be united with Bodies, and fixed for a time.

True Fire may be united with every solid Body on which trial has hitherto been made; and when it is once communicated to it, it will adhere to it a considerable time; and therefore, does not instantly disappear in Bodies, as it does in the *Foci* we have been just treating of.

For if we commit any of these Bodies to a pure strong Fire of any sort, we find that they may be heated so as to shine, grow refulgent, and melt. This, the Experiments of *Tschirnhausen*, *Homburg*, *Hartsoeker*, and others evince; as likewise, those of your Smiths, Cooks, and all others that are conversant about Fires; as well as those which the Earth itself irradiated by the Sun offers to our Observation: In all which the same thing is found to hold good by every kind of Experiment. And this, the trial upon all fixed Earths, all kinds of Stones, Gems, rocky Substances, Glass, fixed Salts, Wood, solid Fossils, and Metals, confirm the truth of. And hence the great *Newton* very justly observes, that if Water itself could be converted into Earth, it might be so impregnated with Fire as to become lucid. Now there is nothing in this affair that deserves more to be taken notice of than this, that there must be some cause, by which the Fire is connected to these Bodies during this time, besides the

the Fire itself. This is plain ; for in *Vilette's Focus*, that intense Fire is destroy'd the very moment that the parallel irradiation ceases. Fire, therefore, in that place, does not hold together and detain Fire : On the contrary, all those Fires now fly asunder, and leave one another, which the instant before were so closely united together. But now, if an iron Ball, whose great Circle, suppose equal to the Circle of the *Focus*, had been held there so long till it was quite hot through ; then, the Fire of this *Focus* being associated with the matter of the Ball, would be detain'd in it a considerable time, and thus this focal Fire, which would otherwise have vanished in a moment, will, now it is received within this body, remain united to it a long while, and be secured from this instantaneous extinction. What now is properly the cause of this effect? Body. By what means does it thus retain Fire? By its corporeal Mass. Was there, therefore, no other corporeal substance in this *Focus* but Fire, the Air itself being expelled by the force of it? And did the Fire, therefore, vanish so suddenly, because there was no other Body to secure and detain it? Do the particles of Fire, then, when collected together, immediately restore themselves to their former *equilibrium*, if they are not kept together by some dense Body? And, hence, is there no mutual attraction between the elements of Fire? Or don't they, rather, repel, and fly from one another?

EXPERIMENT XIX.

When this pure elementary Fire is thus communicated to Bodies, it discovers itself to be real Fire by a true physical effect, which it produces all around them from every point of their surface, so long as it remains in them. And that very pure.

In this case, certainly, we observe the principal mark by which the Thermometer demonstrates that Fire is actually present: For if, as you see, I hold this Thermometer at a certain distance from this red hot Iron, you perceive the Spirit instantly rarefies in the Tube, and so much the more, the nearer I bring it ; and again, you observe it is condensed, as I remove it back again. Nor does it at all signify on which side of the Iron I hold it, if I take care to keep it always at the same distance. This Fire, therefore, that now resides in the Iron, and acts upon the Thermometer, is, in reality, the very same as the former ; but it now persists in this place without any attrition, or parallelism, and produces the very same effects there, as elementary Fire does. Observe, now, this Brimstone Match ; as I bring it very gradually from some distance towards this red hot Iron, you see it begins to smoke, melt, sparkle, shine, and kindle into a Flame. But, again, pray take particular notice of this surprising Experiment that follows. This small Vial in my hand, contains some very pure Alcohol ; a little of which I'll pour very gently and cautiously upon this red hot Iron. What do you imagine, then, will be the consequence? That it will take fire? to be sure no body doubts it. But the case is far otherwise. For observe, as soon as ever it falls into the hollow of the Iron, it forms itself, like Mercury, into a globular figure, and runs up and down in that manner, without the least appearance of any Flame ; and yet you see the moment it comes to the colder part of the same Iron, it is then in an instant dissipated into the Air ; tho' then too, without flaming. What now, Gentlemen, should be the cause of this? Sulphur, Gunpowder, Wood, and other Bodies, when apply'd to this Iron, flame immediately : And yet Alcohol, which being gently

ly heated, fires sooner than almost any thing, is able to bear the Heat of the same Iron, without taking fire. The solution of this Paradox is worthy your penetration.

EXPERIMENT XX.

Without any
increase of
weight,

As appears
by an Expe-
riment made
upon Iron
with a Bal-
lance.

Another up-
on Brass.

Since, therefore, it is certain, that this Fire may be thus detained in a solid Body, and that, during so long a time, and in such a degree; it is our principal business to enquire, of what kind this Fire is, which in this manner remains there: And as weight in particular is one of the chief, and most general properties of Bodies, I have taken pains to examine whether this Fire does in reality add to fixed Bodies any weight that our senses are capable of discerning. To this purpose, then, I made choice of a Body, that would bear a strong Fire without losing any thing of its weight; and at the same time, should be able to receive a large quantity of Fire into it, and preserve it there a considerable time: And I made use of a very accurate ballance, that moved very easily upon its *Axis*. Observe then, this parallelepiped, made of the best sort of Iron, which weighs 5 pounds, 8 ounces, *Amsterdam* weight, now it is cold. I'll put this, as you see, into this large Fire, which shall be blown till the Iron is perfectly red hot all over: Thus bright, then, as it is now it is taken out, when I have struck off the dust, I'll put it into one scale, and at the same time put weights in the other, till there is a perfect *equilibrium*. You observe now the beam is perfectly at rest, and upon examination, you find, that the weights in the scale make exactly 5 pounds, 8 ounces. I'll leave it now in the scale till it is quite cold, and the *equilibrium* will still be maintained: For after letting it alone thus for twenty-four hours, I have found, that even in this large Mass, there was not the least difference in the weight of the Iron when it was red hot, and after it grew cold. I made the same trial with a large solid piece of Brass; and the event was exactly the same. It is necessary, however, to give you this caution, that in making these Experiments, the heated Body sometimes seems to be lighter than it was when it was cold; and this happens when the scales are fastened to the beam with ropes, or any thing of that kind, that is capable of admitting moisture into it; for when the Metal is put into the scale, the heat of it makes the moisture evaporate, and by this means the strings on that side grow lighter than they were before. On this account, therefore, we must always, for this purpose, make use of chains made of Metal.

COROL. I.

Fire is free
in Space and
Body heated.

The Fire, therefore, thus adhering to a heated Body, diffuses itself all around just in the manner of an Atmosphere: For from every point of the Body it exerts its force to a considerable distance, and thus produces those true physical effects that are peculiar to Fire: and these are found always to be the greatest, the nearer you approach to the heated Body. If a Globe, therefore, was thus heated, it would form a Sphere of Heat round it, whose center would be hottest of all.

COROL. 2.

And, hence, we understand, that there is great quantity of true Fire in such a Body;

Body ; and that it continues there for a very considerable time. For if we consider, that round such a Ball of Iron or Brass, there is a great degree of Heat on every side to a considerable distance, as appears by its proper effects ; and at the same time reflect, that during the continuance of this Heat, it must be constantly diminished by the cold of the ambient Air : We shall then easily see, that the quantity of Fire in this heated Ball must at first have been exceeding great. And, hence, the greatest quantity of Fire must be in the Body itself, with respect to the surrounding Air that is heated by it. And again, if such a Sphere is kept in the Fire so long till it is perfectly red hot quite through ; then, in its center the Heat will be most condensed, and greatest of all : The truth of which is confirmed by all its effects.

Greatest in the Center, and decreases towards the Surface,

C O R O L. 3.

But from this center towards the surface, the Fire grows gradually weaker and weaker ; for its surface that is contiguous to the Air, will first be affected with the coldness of that, and, hence, will first grow cold. And this is equally true of the Atmosphere of Air that surrounds the Sphere, for those Orbs which are nearest it, will be hottest, and thence grow successively cooler, till they come to that which determines the boundaries of the Heat, and is itself as cool as the ambient Air. Hence, again, we are certain, that in this whole heated Sphere, the center expands itself every way with the greatest violence. This is the nature of Fire, which is here greatest in the center. But the contiguous Orb will be less expanded, and therefore will confine the expansion of the center, and in some measure repell it ; for this Orb is not quite so hot, that is, it is a little less expanded, or a little more contracted. And, since this same expansion and repulsion will hold true in all the Orbs that compose this whole heated Atmosphere ; hence it appears, that so long as the Heat, communicated to the Sphere, continues greater than that of the common Air, so long there will be a continual dilatation and repercussion throughout the whole Sphere, as well in the solid Mass itself, as the Air that is heated round about it. And this vibration, considering the violence of the Fire, must of necessity be very great. Does therefore the vibration and repercussion in this case agitate the particles one amongst another ? And is there by this means new Fire excited, as we have explained already in the first manner of generating Fire by attrition ?

So that at last it comes to the common temperature.

In a heated Sphere a continued oscillation.

C O R O L. 4.

It were here much to be wished, that we could find a way of determining the proportional quantity of Fire, that is contained in such a Body, with regard to its very substance ! But this is not so easy to accomplish as people generally imagine : For tho' we are able to discover the force of the Fire by its sensible effects ; yet we cannot from its force make a certain judgment of its quantity ; and for this reason in particular, because we don't yet know how much its power may be increased, purely from the near approach of its Elements. So long, therefore, as we are ignorant what proportion the power that depends upon this condensation of Fire, bears to that which arises from its quantity, so long we can't pretend to make use of the effects of Fire, as a certain measure to

The measure of the quantity of this Fire difficult.

determine its quantity. These niceties may to some persons seem unnecessary; but a great deal of caution will never do any harm in physical inquiries.

COROL. 5.

This Fire
does not be-
come a con-
creted Mass
with the
Body,

This Fire, however, tho' it thus continues in a heated Body, does not seem to be concreted with it into one corporeal Mass; for notwithstanding the Body grows bigger than it was before, yet it don't become at all heavier; unless you will suppose, that the Fire may be concreted with it, so as to increase its bulk, without making any addition to its weight. This, in the mean time, we are absolutely certain of, that the Body is constantly extended in its bulk, so long as the Fire remains in it.

COROL. 6.

Nor renders
it lighter;

Nor does the Fire at all lessen the weight of the Body, whilst it is in it, and the Cold restore it again: For the contrary is always found true by Experiment.

COROL. 7.

Nor as to its
weight
makes any
alteration.

Hence, therefore, we may conceive of the Fire, in a red hot Globe of Iron, for instance, as a Fluid, dispersed, both through the Body itself, and all round about it, whose Particles are mov'd every way freely, and without any particular tendency: For if you suppose any determination of them one way more than another, it seems necessarily to follow, that the Mass, when it is thus heated, must be either heavier, or lighter, than it was before.

COROL. 8.

The cause of
the continu-
ance of Fire
in any Body.

There must, therefore, be some cause, by which the Fire is during all this time detained in the heated Body, and which prevents its being dispersed again, as soon as ever it is produc'd. For the Fire in the *Focus of Vilette*, or *Tschirnhausen*, is as strong, nay stronger, than this in this iron Globe; and yet we see that that vanishes in an instant, if it is not every moment renew'd in the same place. Hence, therefore, Fire is not able to keep possession of the place it exists in, but must be retain'd there by somewhat of a quite different nature.

COROL. 9.

First the
Mass itself.

Let us examine now this affair ever so nicely, we find nothing here that can effect this but the Body itself, considered as it stands in opposition to Space, viz. as it is somewhat resisting and impenetrable, or, as it is a real corporeal Mass: For it appears by Experiment, that if Fire is communicated by the same cause to Bodies of different densities, they will indeed acquire exactly the same degree of Heat; but then it will afterwards be retained in them so much the longer, as they are denser, heavier, or contain a greater quantity of matter under the same bulk. If you immerse, for instance, bodies of different specific Gravities in boiling Water, and keep them there till they are equally hot; then those that are very heavy, will keep hot for a considerable time, whereas the light ones will grow cold immediately. And as far as we have been hitherto able to judge by Experiment, this seems to be almost a general rule: *Toricellius's Vacuum* loses the Heat generated there instantaneously; Air heated in a vessel,

a vessel, very quickly; Alcohol still slower; Water retains its Heat yet longer than Alcohol; and Mercury longest of all. In the same manner among Solids; Wood, Stones, Metals, if they are made equally hot, are exactly so much the longer before they grow cold, as they are denser than one another.

But again, a greater degree of Fire is longer disengaging itself from Bodies to which it is united, than a less: So that it seems to hold almost generally true, that the greater the degree of Heat is, that is communicated to the same Body, or the more it is expanded by the force of the Fire till it begins to be melted, so much the longer will it always be, before it grows cold: For if you take two Bodies, that are perfectly alike, and give them different degrees of Heat; then the hottest, after it has lost the surplus of Heat by which it exceeded the cooler, will still remain as hot as the other was at first, and consequently will then require as much time to grow cold in as that did. But it still remains nicely to be examined, whether there is not some other cause, besides the density of Bodies, and the degree of Heat, that is capable of preserving Fire for a considerable time, when once it is generated? If Water, for instance, and Oil, should be heated to the same degree, supposing the Oil lighter than the Water, which of these two would grow coldest within the same time? Why, certainly, the Philosophers would generally imagine, that the Fire being intangled by the tenacity of the Oil would remain longer there, than it would in the Water. To determine this, therefore, I took two vessels of the same size, one of which I filled with Water, and the other with Oil of Olives. These I put into boiling Water, and kept them there till I was sure, that both of them had acquired the same degree of Heat with the Water which was kept continually boiling. I then took them out, and placed them both in the same Air, in order to discover the time in which they would be reduced to the same temperature with it, and I found it to be exactly in proportion to their comparative weights.

Secondly, the quantity of Fire.

There seems, in the mean time, to be some very abstruse cause, why Fire itself, nay a very strong one too, is not able to heat Bodies beyond a certain degree; as we see in Water, Alcohol, Oil, and Mercury, when they are once made to boil. As ebullition, however, does not happen equally soon in all, hence lighter liquors are very often capable of receiving a greater degree of Heat than heavier, if they take up a longer time before they boil. Water, for instance, is heavier than Oil of Linseed; boiling Water has 213 degrees of Heat in it, and can, then, with the strongest Fire be made no hotter: This Oil, which is so much lighter, requires a greater Fire, and is longer before it boils, and has then acquired almost 600 degrees. Who, now, is able to account for this? Mercury, we see, which is 15 times heavier than this Oil, arrives only to just the same degree of Heat when it is made to boil. Hence, however, it appears evident, that there is something else besides the corporeal mass, that makes some Bodies susceptible of a certain quantity of Fire only; whilst others are capable of receiving a great deal more. The true cause of this, perhaps, no body is able to assign.

Of which a greater may be communicated to some particular Bodies than others.

From these considerations, however, we see plainly the reason, why Fire that is raised by combustible matter, may be extinguished by Water; for by this means it is incompassed with a less degree of Heat than is necessary to set these combustibles on fire, which is always greater than 213,

Why does Water extinguish Fire.

And.

Why does
Water keep
Tin from
melting.

And for the same reason, a strong Fire won't melt a tin vessel when it is full of Water: For this requires a greater degree of Heat to put it in fusion than that of boiling Water, which is all it can receive so long as the Water remains in it. But set, now, this same vessel on a Fire with Oil in it, and you will find it will soon be melted before the Oil begins to boil. The same thing is true, too, of Lead if you put it on the Fire with Water in it. From a careful examination of all these circumstances it seems probable, that when the Fire has so disposed Bodies, that it can pass, and exert itself equably through their Pores, then, no more Fire can be united with them, than what is actually in them at that time; and this seems to be the case in Fluids as soon as ever they begin to boil; in Solids, when the force of the Fire has perfectly melted them, so as to make them run in the form of a sparkling, or boiling Fluid, which we find happen in Metals, Glass, Salts, and other Bodies thus put in fusion.

By the help, then, of these useful Observations, we learn at last, that there is in reality some *nexus*, or connexion between Fire, and Bodies: That the greater it is the longer it adheres to them: That the same degree of Fire remains longest, in those that are densest: That a greater quantity of Fire may be united with some certain Bodies, oily ones in particular, than other: That these require a stronger Fire, and a longer time to acquire this greater degree of heat: That the denser bodies are, the longer they are before they grow actually hot with rarer Bodies, when they are exposed to the same degree of Heat: And that when they are heated they require so much the longer time to be reduced to the same temperature with these rarer, which grow cold sooner. Now whoever rightly considers these things will understand a great many of Nature's laws with regard to the properties of Fire, which are confirmed by Observation, and if carefully attended to, will be of excellent service in our Philosophical Inquiries. And it is my opinion, if this doctrine should be still farther improved, we may at last from Experiment be able to solve the following Problems: *To fill a given Space with such a Body, as cannot be heated by the greatest Fire beyond a determined degree:* And again, *To fill a given space with such a Body, as shall be able to retain in it the greatest possible Fire.* Is not Iron, which is fused with more difficulty than Gold, hotter when it is in fusion than melted Gold, though that is denser? The thing is worth inquiring into.

COROL. 10.

Heat presently disappears upon the application of a dense cold Fluid.

But whilst we are engaged upon this head, there is another *Phænomenon*, that offers itself to our Observation, *viz.* that when Bodies have a greater quantity of Fire in them than the ambient Fluids, or neighbouring Bodies, then, the denser the Fluid is into which they are immersed in order to be cooled, the sooner will they lose their Heat. My meaning is this, Take three vessels, one full of Air, another of Water, and a third of Mercury, when they are all three exactly of the same temperature: And let three equal pieces of iron be made perfectly red hot. Let, then, the degree of Heat in the Air be observed, and let one of the pieces be left in that; let the other be immersed in the Water, which is exactly as cold as the Air at that time; and let the third be thrust into the Mercury, of the same temperature, too, as the former: What then will be the consequence? In the rare Air the Iron will

keep

keep its Heat a long time; in the Water it will lose it sooner; but soonest of all in the Mercury. And, indeed, it seems to grow cold so much sooner in the Water than in the Air, as the Water is denser than the Air, that is, 800 times. And that in the Mercury, perhaps, 14 times sooner than that in the Water. And this, your Workers in Metals are well acquainted with, who, when they would soften their Metal for particular uses, make it perfectly red hot in the summer time, and then leave it in the Fire which will gradually moulder away to Ashes, and thus let them all grow cold together: But on the other hand, when they want it hard for other purposes, they chuse the Winter for this work, and instantly throw it into the coldest Water they can get.

Thus then, we see there are two causes that hasten the cooling of Bodies when they are heated; viz. the Coldness, and Density, of the Fluid into which they are immersed. But there is yet a third which promotes the same end, and that is, the moving the hot Body about in the cold Fluid; which is the most expeditious way of cooling it; for by this means it is continually exposed to some new cold part of the Fluid. Hence, then, we see the physical reason of that method which is made use of, when we would render Iron as hard as possible, viz. the drawing it swiftly through very cold Water when it is just ready to melt, so that it may be perfectly cooled in an instant: For by this means the Elements of the Iron, which were vastly relaxed, and softened by the Fire, are now intimately united, condensed, and compressed together by this sudden Cold that is on every side applied to them; and, hence, after they grow cold they remain most closely compacted together, and exceeding hard, though at the same time very brittle.

The cause of refrigeration three-fold.

COROL. II.

Whence, then, does it come to pass, that the denser Fluid should so soon cool the hot Body that is put into it? Before this was immersed, the Fluids were all equally cold, and consequently, one's cooling the hot Body sooner than the other cannot proceed from any difference in their coldness. Does the denser matter, therefore, of the cold Fluid attract more Fire out of the hot Body, and that, in proportion to its density? For the determining this question we must again have recourse to Experiments. To this purpose, then, take two equal quantities of the same Fluid (Vinegar, for instance, Water, Alcohol, or Oil) and give them different degrees of Heat; and you will find if you put them together at once, and mix them intimately with one another, they will acquire a degree of Heat, which will be half the excess of the hotter above the cooler. For example, If a pint of boiling Water 212 degrees hot, is mixed in this manner with a pint of the same Fluid, that has but 32 degrees of Heat, then this Mixture will have 90 degrees, which is half 180, the difference betwixt 212, and 32. Hence it appears, that this distribution of the Fire is in proportion to the bulk; and that, therefore, when Bodies of the same nature are mixed together, the one hot, and the other cold, the Fire immediately disengages itself from its contact with the Elements of the former, and unites itself with those of the latter, till this becomes as hot as the other. This, then, being constantly the case, we see that the common degree of Heat is destroyed, and the difference is then equally distributed through them both. But, now, if this Experiment is made with Mercury, and Water, exactly of the same measure, but different degrees of Heat, and these are in the same manner

Why do dense Fluids destroy Heat soonest.

The effect of mixing a hot and cold Fluid.

swiftly

swiftly mixed together; then the Heat that is produced by this Mixture, will be very different from what was observed in that just now mentioned.

And the
difference
observed
here.

For if the bulk of the Water, and Mercury to be mixed, is exactly equal, but the Water is hotter than the Mercury; then, the Heat of the Mixture will be always greater than half the difference of their separate Heats. And, on the other hand, if the Mercury is hotter than the Water; then, the degree of Heat in the Mixture will be constantly less than half this difference. And this diversity is always found to be the same, as if, in the first case, you had mixed three parts of hot Water with two of cold; and in the second, you had mixed three parts of cold Water with two of hot. But, now, if the bulk of the Mercury is to that of the Water, as three is to two; then, it don't signify at all, whether you heat the Mercury, or the Water: For the mixture will always have a degree of Heat equal to half the difference of their separate Heats, as we found to be the case when we mixed the Water together in equal quantities.

Fire is di-
stributed
through
Bodies in
proportion to
their Bulk.

In this Experiment, then, we plainly discover the law by which nature distributes Fire through Bodies; which is not in proportion to their densities, but in the same manner as it is diffused through space. For though the specific gravity of Mercury is to that of Water pretty nearly as 14 to 1; yet its power of producing Heat when measured by its effect, appears to be only the same, as if Water had been mixed with an equal quantity of Water. But the same thing is abundantly confirmed by every kind of Experiment as I took notice before, when I told you, that I had been convinced by Experiment, that all sorts of Bodies, if they are long enough exposed to the same common temperature, acquire exactly the very same Heat, or Fire, without any difference at all except what arises from the different spaces they take up: That, hence, it did not appear from Observation, that any Bodies whatever have a power of attracting Fire, though their greater density makes them capable of retaining it longer when once it is united with them. The Experiments, I have just mentioned, were performed for me by the famous *Fahrenheit*. What then is the reason, that Fire will leave the Body it possesses, to enter into a heavy Body, so much sooner than into the most light, and subtil space, into which one would imagine it should penetrate with a great deal more ease?

COROL. 12.

The greatest
Bodies retain
Heat long-
est.

Hence, again, we understand that the bigger any particular Body is, the longer it will *cæteris paribus* keep the Heat it has once conceived: For the density of the outward surface always prevents the quick egress of the Fire which endeavours from the inward parts to make its way out. The next orb then restrains the third, this the fourth, and so on to the end. And for this reason if a Body is heated perfectly through, its inmost parts are always longest a cooling. Hence, therefore, since the magnitude of any Body is capable of farther increase, it may at last become so large, that the Heat communicated to it, shall continue in it a prodigious long time.

COROL. 13.

It is demonstrated by the Geometricians, that if Bodies remain the same in all

all other circumstances, the bigger they are, the less surface they will always have in proportion to their solidity. Hence, again, if we consider, it will presently appear that very large Bodies, if they are once heated, must on this account retain their Heat a very considerable time. From this law, then, it follows that every Body will preserve its Heat so much the longer, as it has more solidity contained under a less surface; that is, in comparison of others.

As well as
Bodies of the
least Surface.

But again, the Mathematicians have proved, that if the corporeal mass continues the same, a Body can never be reduced under a less surface than when it is formed into a Sphere. This Figure, then, is the most tenacious of Heat; both on account of the smallness of its surface in respect of its solidity; and the equal distribution of all the parts quite to the center, and the equal recess from the surface. Hence, a very large spherical Body, if it is once heated, will retain its Heat a vast while. And this possibly may be one reason of the globular figure of the Sun, and the fixt Stars.

Hence spher-
ical ones.

COROL. 14.

When a Body is divided into parts, without any other alteration, then its surface will be always increased, though its quantity of matter continues the same; and then it will, of consequence, constantly grow cold so much the sooner. A Cube by being divided into two equal parallelipeds, has $\frac{1}{3}$ more surface than it had before. A Sphere by being split into two Hemispheres, has its surface enlarged by the Area of two great circles, which is equal to $[\frac{2}{4}]$ of the surface of the Sphere: And, hence, if they were heated, and afterwards thus divided, they would lose their Heat so much the sooner. The dividing, therefore, of a hot Body into smaller parts, and the reducing it from a spherical surface to a plain one, are two causes, by which the cooling it will be chiefly promoted; for its contact with colder Bodies will, by this means, be wonderfully increased. A pint of boiling Water reduced to a spherical figure, will retain its Heat for a long time; but if it is poured upon a large cold plate of Iron it grows cold in an instant.

When they
are divided
they cool
sooner.

COROL. 15.

Now the right consideration of these things, will help us to discover the reason of the continuance of Heat in other cases likewise. It is an old Observation, that those Bodies, that are dense, hard, strong, are used to exercise, and are filled with compact heavy Fluids, are always found to be hotter, and to be longer growing cold than others, for the solution of which, a great many very different causes have been assigned: But from what has been said, it plainly appears that such Bodies must, by the strong application of their solids to their Fluids, condense them by this compression, and of consequence, collect more Fire within them, and retain it very tenaciously when it is united with them. In the same manner it is observed, that in dead Bodies, that want this vital Warmth, the internal parts cool very leisurely. the external very quickly. The reason of this is evident from what has been laid down; nor is there any need to suppose a vestal Fire in the internal *Viscera* to account for this *Phænomenon*. On the other hand now, your lax, soft, unactive, weak Bodies can never communicate so much Heat to their watery humours; for they always suffer less attrition, are less condensed, and are relaxed into larger

The differ-
ent Heat of
Human
Bodies.

larger surfaces ; and for this reason too, are not disposed so much as to retain the Heat when once it is generated. Hence, then, we see, what ill consequences are to be feared from both these extremes ; and what kind of Medicine, in particular, should be made use of, if we expect a happy success in the curing them. And thus the usefulness of this doctrine becomes very extensive.

COROL. 16.

Where is the
greatest
Heat in the
Human
Body?

What is the
Heat of the
Air we in-
spire?

Now I am upon this subject, I can't help making use of this doctrine of the refrigeration of Bodies to give a solution of that question, which has so much exercised the skill of the Chemists, Physicians, and Philosophers ; viz. whether the human Blood has the greatest degree of Heat in the Heart ? And if this is the case, what is the reason of it ? What dissertations do we find amongst Authors upon this subject ! and what very different opinions about it ! This affair, therefore, I will endeavour to explain in the simple manner following. In the veins the blood is coldest. This is universally agreed on, and therefore needs no demonstration : It returns from those parts that are farthest from the Heart ; and from the external parts which are coldest ; it is mixed with the new juices that are received into the Body, which are rather colder than itself ; it circulates in a weak, large, lax, unactive vessel ; and is thus discharged into the right ventricle of the Heart. For these reasons, therefore, the venal Blood of itself would be colder in no part of the Body than in this right ventricle. But as such a degree of Cold in the Heart would be prejudicial to the Human Body, and even endanger life itself ; hence, the Blood in its return through the Veins to the Heart, is rendered something warmer, by the Heat supplied by Arteries, which is communicated to the Body, and applied to the Veins. Notwithstanding this, however, the venal Blood is coldest of all in the right ventricle if compared with the arterial. But this cool Blood, now, being pressed, and driven into the narrow, elastic, strong branches of the pulmonary Artery, by the force of the right ventricle, and the vast action of respiration, must necessarily pass through the Lungs alone, in as great a quantity as it does through the whole Body, and all its parts, in the same time. Hence, therefore, the Blood would in no part of the Body, suffer so great an attrition, and of consequence acquire so much Heat as in the Lungs alone. But this degree of Heat, again, would be intolerable, and more than we could be able to support ourselves under. This, therefore, nature has secured us against by the Air we draw into the Lungs in inspiration, which is always a great deal colder than the Blood. And it appears from the Observations of the ingenious *Malpighi*, that the Blood is here distributed through a vast number of exceeding fine Arteries, which are applied all around the thin vesicles of the Lungs, and by this means is exposed to the Air under a prodigious large Surface ; but the Air is every moment renewed, and therefore always cold ; and, hence, the Blood, of itself, is cooled in no part of the Body more, in this respect, than it is in the Lungs. Is not this, now, very surprizing, that in the very same part of the Body, where for some necessary uses the Blood must have the greatest degree of Heat, there again, for reasons as necessary as the former, it should require the greatest cooling ? The Blood, and recent Chyle, could not be propelled through all the vital pipes of the whole machine without endangering the animal life, if it was not first vastly divided, and reduced into its most subtil Elements by the forcible attrition of the Lungs ;

Lungs; but this could not be effected without a great production of Heat: Should this Heat, however, thus communicated to the Blood remain in it, and there should be other causes to cool it at the very same time; certainly the Blood, in a very little while, would intirely putrify, and we should die of a most pestilential disease. By accident, I observed some time ago, in that part of the Sugar houses where the Sugar loaves are dried, that the Air was so exceeding dry, and hot, that I could not stay in it a moment without danger of present suffocation. I thought, therefore, I had got a very good opportunity of examining the degrees of Heat in the Air that Animals could breath in; but though I was vastly intent upon it, the multitude of my affairs, that could not be dispensed with, necessarily called me another way. I desired, therefore, that industrious Gentleman Mr. *Fabrenheit*, whom I have so often mentioned with respect, and my very good friend and kinsman *Jodocus Provost*, to make some Experiments for me in the manner I should direct, and to let me know exactly the success. This they were so good as to comply with, and gave me the following account, upon hearing which, I am apt to think you will be of opinion with me, that there is scarce any Experiment to be met with that will help us better to understand the effects of this heat of Air upon the Bodies, Humours, and parts of Animals. Nor, perhaps, is there any other, that is of greater service in the Art of Chemistry.

The Baker, then, in one of these Sugar houses was heated till an accurate mercurial Thermometer, after it had remained in it a sufficient time, rose to 146 degrees. A Sparrow was then set down in it in a cage, at six a clock in the evening. When it had been there about a minute, it began to open its mouth, and pant with a great deal of trouble, and uneasiness, the number of respirations increasing every moment, so that in a very short time the repetition of them was vastly quick, and with such a diminution of strength, that he could sit no longer upon his perch, but leaving it went to the bottom of the cage, where, with violent struggling, and panting, he died within seven minutes. At the same time a Dog was confined in the same hot room; who, after he had been there seven minutes, by opening his mouth, lolling out his tongue, and breathing very quick gave evident proofs that this great Heat was not a little troublesome. He remained, however, at that time quiet in the wooden cage in which he was inclosed. When a quarter of an hour was near passed, he began to breath very strong, and with a great deal of noise, and made such efforts to get out of his confinement, as were quite surprizing. A little afterwards his strength failed him, his respiration began to grow slower, and slower, till at last each inspiration, and respiration continued a long time, though they were still performed with a great deal of force. These, however, grew afterwards more and more languid, so that a little before his death they could not be heard at all. During all this time, a great quantity of *Saliva* ran out of his mouth, which was perfectly reddish, and stank so intolerably, that no body present was able to bear it: And this terrible smell, thus suddenly produced in the Animal, was of so hurtful a nature, that one of the persons that was making the Experiments, upon coming near him, was in an instant fainting away, so that it was necessary to refresh him with some Spirit of Wine, and Myrrh; by which means it happened, that he could not put the Thermometer into the mouth of the Dog the very moment he died. A little afterwards,

The wonderful effects
of hot Air.

afterwards, however, being recovered by the abovementioned liquor, he thrust it in, and the Mercury stood at the degree 110. In this very great Heat now, and with all these vast struggles, there did not appear upon the dog the least sign of sweat. This Dog weighed ten pounds. At the same time these Experiments were made upon the Sparrow, and Dog, a Cat, too, was shut up in a wooden cage, and placed in the same stove. When she had been there a minute, she began to lay upon the ground, and pant; and in a quarter of an hour made a hissing noise as she breathed; she then struggled prodigious hard to get out, and after she had suffered exactly in the same manner as the former, underwent at last the same fate: But she was all over as wet with sweat as if she had been taken out of a River.

We learn evidently, then, by these Experiments, that the Air when it is $\dagger$ 48 degrees hotter than the Blood in the mouth of a healthy child, is capable of producing the most acute disease in an instant, and soon after destroying the Animal with the most terrible symptoms. But how surprizingly must all the humours of the Body here be changed, as they gave such evident signs of a most fetid putrefaction? Certainly there is not in nature a more abominable stench than this terrible rancid one, more loathsome than that of a dead carcass, which was so soon produced, and exhaled from this Animal which was perfectly well but just before? For this, we see, purely by its contagious quality, brought a strong man, and one used to labour into imminent danger of present death. And what greater proof can we have that all the Juices were resolved, and changed from their natural disposition, then, that even the *Saliva* in so short a time was become red. But the Fire of the room did not alone effect all this; for the flesh of the dead Animal, being hung up in the same Heat, was only dried thereby, and did not dissolve into such a noisome *sanies*. But the vital motion in these creatures, whilst by its attrition it generated Heat and a Tendency to putrefaction, must of necessity have produced a prodigious degree of Heat in the Lungs; and these having nothing to help to cool them, the Heat must have grown much greater there than even in the stove itself. And, hence, the Oils, Salts, and Spirits of these Animals were reduced to putrefaction within, perhaps, 28 minutes; whilst the Bird was affected within one. And here we may observe, when these rooms are heated to such a degree, the servants, who are obliged to attend there, stay in but a very little while at a time, and then go out for some refreshment. In the same manner, in the Melting-houses, where they cut the melted iron into large plates, the Workmen can bear the excessive Heat but for a moment, and then are forced to retire into some cooler Air, where they lie down, and recover themselves, or otherwise they would instantly fall into a *Deliquium*. And whenever the Air is heated but to such a degree, as is the standard of a man in health; if a person is then placed in it, he soon perceives the excess of the Heat, which grows so troublesome, that he can't remain in it any considerable time, but strives with all his might to get into some cooler place, or otherwise would faint away. Hence, therefore, we see, that hot Air enervates the strength; cold restores it: And, indeed, except the Heat was tempered by an alternate interposition of Cold, there would soon be an end, both of Plants, and Animals.

$\dagger$ This must be understood in the very greatest latitude in which it is ever observed; the Heat of a child in health very rarely rising higher than the 96th degree in *Fahrenheit's* Thermometer.

From what has been said, then, we at last make this conclusion; that the Heat of the Blood in the Veins, Arteries, Heart, Lungs, and other parts of the Body, is pretty equable. In the Lungs, however, it is, in reality, both hottest, and coldest; and hence, tho' it undergoes those effects in the Lungs, which are absolutely necessary, yet by this means it is still kept of a proper temperature.

COROL. 17.

The larger any Body is, the denser the matter is of which it consists, and the more exactly spherical its figure is, the more disposed will it be to retain the Fire which it has received into it; which is every where confirmed by Experiment. If such a Body as this, therefore, should be placed in an exceeding rare Fluid, or in a perfect *Vacuum*; then, all the physical causes that are at present known to promote this preservation of Heat, would be united together.

What Bodies do contain their Heat longest.

COROL. 18.

Nevertheless, all the solid, large, spherical Bodies, that we are conversant with, tho' they are brought to the very point of fusion, if they are placed in the common Air, soon return to the temperature of the ambient Atmosphere.

Even these grow cold.

COROL. 19.

Can we then look upon the vibration of the constituent Elements of Bodies, as the whole, and only cause, that Fire continues in a Body that is heated? As was the opinion of the illustrious *Newton*. It is true, indeed, if a large Bell is struck but in one place with an elastic metal Clapper, it will continue its sonorous undulations for some seconds, and its tremulous concussions a good while after we are able to hear them, as appears by sprinkling a little Sand on it: But in other cases, this vibratory motion of elastic Bodies is commonly pretty soon over.

What does vibration do towards Heat?

EXPERIMENT XXI.

The denser Bodies are, whether fluid, or solid, the longer time they require to grow equally hot, if they are exposed to the same Fire.

Dense Bodies are longer heating.

For making this Experiment, take a brass hollow Parallelepiped, open at top, and filled with Water; upon this, let there be placed some cylindrical glass Vessels of the same size, and filled to the same height with Fluids of different specific Gravities: Then, if you make a Fire underneath, so that the Water being constantly in motion, may acquire a very equable degree of Heat, you may with the naked eye perceive the lightest, and consequently, the rarest Fluid to be expanded very soon, but the densest a great deal slower; and the same is confirmed by the application of the Thermometer. Air grows hot very quickly, then Alcohol, next very liquid *Petroleum*, then Oil of Turpentine, and then in order, pure Water, salt Water, very strong *Lixiviums*, Metals, Mercury, Gold.

COROL. I.

The matter, therefore, of Bodies, both admits, and parts with Fire, with some

some difficulty ; and hence, Body, as Body, does, in this respect, retain its temperature, nor suffers it to be changed without some resistance.

EXPERIMENT XXII.

The larger Bodies are, the longer they are, *cæteris paribus*, in growing hot with the same Fire ; and the contrary. The truth of this is so well known from the most common Experiments, that it may be almost made use of as a physical Axiom.

EXPERIMENT XXIII.

What Bodies are heated with the most difficulty ?

The denser and larger Bodies are at the same time, and the more exactly spherical their figure is, the more Fire they require, and the longer they are, before they arrive at their greatest Heat. For if one pound of Iron is hammered into a thin parallelipidal Plate, and another is form'd into a Sphere, and both these are immersed into boiling Water ; then, the Plate will soon receive the Heat of the Water, but the Sphere slowly : So far therefore, the Surface seems to determine the time, which a Body takes up, in admitting, and parting with Heat, and Cold.

EXPERIMENT XXIV.

No Body of itself hotter than every other.

Among all the Bodies of the universe, that have hitherto been discovered and examined, there never was yet found any one, that had spontaneously, and from its own nature, a greater degree of Heat than any other. This surprising paradox has already appeared to be true by an induction of particulars : For, as I informed you before from Experiment, all those Bodies which are esteemed the hottest, will be reduced exactly to the same degree of Heat, or Cold, if they continue a good while in Air of the same temperature. Certainly, Phosphorus itself made of Urine, is as cold as the ambient Water, whilst it is immersed in it ; tho' it soon grows exceeding active, and hot, when it is exposed to the Air. In like manner the Phosphorus that is prepared from calcin'd pinguious substances, and Alum, so long as it is secur'd in its glass Vial, has no more Heat than the Glass, nor has the least effect upon it ; tho' upon the admission of the Air, indeed, it takes Fire, and burns immediately. Linseed Oil, which is never harden'd into a solid Mass, but remains always fluid in the greatest natural Cold, is even at that time as cold as the coldest Ice. Nor is the choicest Alcohol then at all warmer than the purest Mercury. That wonderful Spirit of Nitre, called the fiery Spirit, which is a curious preparation of *Glauber's*, and that distilled Oil, which the Chemists draw from Saffras, whilst they remain quiet in close Vessels, are as cold before the mixture, as the coldest Ice ; tho' when they are mixt together, they produce a most terrible Fire. The coldest Steel and Flint, by a momentaneous percussion, excite in the sharpest frosty Air, the most intense Fire that we are at present acquainted with. And this is so universally true, that of all the natural Bodies that have hitherto been examined, there has not been found one, that of itself inclines more towards Heat, than Cold, not one, that is naturally hotter than the rest. I know people are generally strongly prejudiced in favour of the contrary opinion, and think it evident, that the Bodies of Animals, at least, have a greater degree of Heat in them, than others. And this, I confess, is true, if you consider them whilst they are alive ; for so long there is a perpetual

collection of Fire, and communication of Heat, by that attrition of the parts, which is necessary to the support of the animal life : But, now, if you examine a drowned Body, that was just before strong, and in perfect health, and remains still in all respects exactly the same, except wanting this vital attrition ; you will then find it exactly as cold as the Water. But you'll be apt to say, sure the contrary of this appears to be true ; for we often see, that Bodies have a great degree of Heat after they're dead. And this, Gentlemen, I acknowledge to be frequently the case. Hence, you'll probably insist, that there **are** in reality, therefore, Bodies of Animals, that are disposed to keep up, and cherish Heat in them. Nor do I deny it : But then please to consider, that when this is the case, then putrefaction is actually begun, by which there is excited a constant, and pretty violent motion too, which by its attrition, and friction, is capable of communicating new Fire to the Body, which did not naturally belong to it. Take for instance, a quantity of cold Hay, press it hard down in a large heap, and then moisten it quite through with Water, and it will by this means grow very hot, and sometimes burst out into Flames. Fermentation, putrefaction, effervescence, and the mixture of Bodies together, will certainly very often produce the greatest degrees of Heat, as I shall hereafter expressly demonstrate, nor ever deny'd ; but then these motions are never observ'd to happen in one single simple Body alone, and therefore are never spontaneous, or belong properly to any Body in particular. Any other objection of this kind that may be raised against what we have asserted, you yourselves will easily be able to answer.

COROL. 1.

Does therefore a dense Body receive more of the substance of Fire into it, as it grows by degrees hotter and hotter ? Is this greater comparative quantity of Fire, owing to the greater degree of Fire that the Body is exposed to ? And is the continued application of this Fire likewise another reason, that a Body thus heated has a greater quantity of Fire communicated to it ?

COROL. 2.

Is Fire itself, that is so long insinuating itself into a Body, and enters into it in so great a quantity, the true physical cause of the long retention of the Fire in the Body when it is once heated ?

COROL. 3.

Or rather, is not this effected, by the heated corporeal Mass, and the Fire communicated to it, both their powers conspiring, and being united together ?

SCHOLIUM.

Thus far, Gentlemen, I have endeavoured by a few simple Experiments, to lay before you those evident truths that I have been able to discover, concerning the nature of that Fire, which Philosophers call elementary Fire. And this we have considered : First, as it is a created Being, existing separately, and without every other Body whatever ; then, as it resides in Bodies, and remains there pure and simple, nor receives any *Pabulum* from them, being determined in parallel or converging Rays ; and lastly, as the same is collected

Conclusion
of the doc-
trine of ele-
mentary
Fire.

in

in Bodies, purely by motion and attrition. And I have taken a great deal of pains to give you a right notion of this Fire, before I proceed to examine into that, which is supported by combustible matter, which is supposed to be of quite another nature from the former, and differs very much from it in its effects: For the not carefully distinguishing betwixt these two kind of Beings, which by universal consent are called Fire, has given rise to a great many errors in the chemical Art. Let us now, therefore, set about the examination of common Fire, which by many people is looked upon as the only real Fire. Give me leave, however, before I proceed, to give you a short account of some observations that may be understood from the doctrine that has been already laid down, and which properly belong to the History of Fire; that so both this History may be as compleat as possible, and every person may have the honour of his proper discoveries.

The Discoveries of other Authors.

An iron Rod a foot long, made red hot, gained $\frac{1}{60}$ of its length. A glass Cylinder, a span long, made red hot, gained $\frac{1}{50}$. *Sturm. Coll.* part II. p. 101. A metal Ring made red hot, had its diameter increased by $\frac{9}{1000}$. *Sagg. di Nat. Sper.* p. 182. A glass Globe was distended in its capacity $\frac{1}{1000}$, purely by the Heat of the hand. *Des Amontons, Mem. de l'Ac. Roy.* 1704. p. 12. 1705. p. 4. If a Thermometer is immerg'd into a warmer liquor than itself, it first descends, and afterwards ascends; if into a colder, it first ascends, then descends. *Sagg. di Nat. Sper.* p. 178. ad 181. And this is proved by a great many arguments to depend in the first case upon the expansion, and in the second upon the contraction of the Glass, before the included fluid can be equally affected, *ibid.* In warming of Liquors, the Heat is supposed not to expand them equably, but by alternate impulses. *Halley. Phil. Transf. Abr.* T. II. p. 34. Mercury being put in a glass Vial, and then immerg'd in cold Water, which was afterwards heated by degrees, till it began to boil, ascended very equably; but when the Water boiled, tho' the Fire was increased, it could not be dilated any farther, but remain'd at the same point. Hence, therefore, Thermometers made with Mercury, will be most accurate. *Id. ibid.* And these following observations I choose here to subjoin, as matters that deserve consideration: Since one very often corrects another. If two metal Rods are of the same weight when they are cold; then, if you make one of them hot, and hang it to a balance, it will be lighter than the cold one; but if you place a live Coal under the cold one, the equilibrium will be again restored. If two metal Rods are exactly in equilibrium, then by holding a hot Coal over either of them it will grow lighter, and on the contrary will preponderate if you hold it underneath. *Sagg. di Nat. Sper.* p. 256.

Of the Pabulum of Fire.

Fire in Bodies in a twofold manner.

Since, then, it appears almost certain, that the very same Fire does always exist, in the same quantity, and without alteration; and farther, that when it is collected in some sort of Bodies, such for instance, as Gold or Silver, it will continue in them a considerable time, without any perceptible destruction of them; we come now in the next place to examine those Bodies to which Fire may be likewise communicated, and in which it may be preserved too a pretty while, but then, under this circumstance, that at the same time that the Fire is thus detained in them, nay, and sometimes increased, the very Bodies themselves

selves are so far consumed in this action, that they almost disappear from our senses. For when Fire is once collected in Bodies in this manner, it generally remains in them, and persists in its activity, till it has dissipated those parts of them, by which it was continually supported: But as soon as ever these parts are dispersed by the power of it, then the Fire likewise disappears too, exerting itself but very little longer upon those that are left behind.

Since therefore the Fire itself, and the Body in which it was collected vanish from our senses both together, hence people have universally called those Bodies, or those particular parts of them, the Aliment, or *Pabulum* of Fire: And thus far it may be allow'd, without any inconvenience. But when they pretend to call them so in too strict a sense, because they look upon them as the nutriment of real Fire, and imagine them to be changed by the Fire into the very substance of elementary Fire, and thus to have their own proper nature destroy'd, and to put on that of Fire; then, they propose something vastly different, which ought very well to be considered before it's admitted for true; for tho' the assertion of it is very easy, yet the demonstration of it is exceeding difficult. And certainly, whoever overhastily runs into this opinion, must necessarily suppose, that those Bodies which nourish, and support Fire, in the manner we have mentioned, are by this means constantly diminishing: And hence the quantity of all other Bodies in the universe must be continually lessened, whilst that of elementary Fire must be in proportion increased. Of consequence, therefore, Fire being thus perpetually augmented, and at the same time diminishing every thing else, would necessarily have destroyed all other Bodies long enough ago, and remained superiour, and alone in the Universe. In the mean time, however, if we examine the observations that have been made from the most ancient times, quite down to our own, we shan't find the least indication of any such increase. But on the contrary, the power, and consequently, the quantity of Fire is observed to continue the same, nor seems by any means to suffer any considerable augmentation or diminution. An Example, or rather Proof of this, are those very accurate Meteorological Tables, so nicely contrived, and so carefully perfected many years ago for public service, by that excellent Geometrician *Nicolaus Cruquius*, in which you may see what an extraordinary *equilibrium* of Heat is maintained. Nor is it a little to our purpose, that after burning of Woods, which has been continued sometimes for whole months together, there has never appeared the least sign of any increase of Heat remaining after it was over. Can you believe, Gentlemen, that after almost six thousand years, as in this time all the combustible matter of the whole inhabited Earth, where Fires are in use, must necessarily have been so many times consumed; I say, can you believe, that after all this long and constant augmentation of Fire, the Heat should not yet be grown intolerable to tender Plants, and Animals? In every part of the world at least, the Heat has always continued the same: For the very same warmth of the Air is always requisite, that the tender *Embryo's* of Plants, whilst they lie inclosed in their Seeds, and are nourish'd, fill'd, and distended with a kindly moisture, may expand their very fine, and feeble *Stamina*; for if the Heat increases beyond the bounds they are able to bear, it soon burns up the almost fluid Machine in its original state; nor does it less certainly perish if the Heat grows too languid: Why should I make mention of Animals? The animalcles of the

Why some Bodies are called the *Pabulum* of Fire.

Does this *Pabulum* become Fire itself?

Male Seed, when they have insinuated themselves into the Eggs of the Female, require such an exact temperature, that the 100th degree of Heat in *Fahrenheit's* Thermometer will burn them to death, and in the 70th, by reason of the Cold, they will hardly ever be brought to maturity: Nay, the very impregnated Eggs of Insects, that are able to bear the sharpest winter Frosts, are most certainly destroyed, if they are exposed to a degree of Heat that's a little too intense. In short, therefore, examine Nature in her whole extent, and you'll evidently find, that the quantity of Fire in the Universe, always continues the same: For it's certain, after so many terrible conflagrations occasion'd by Meteors; after such prodigious eruptions of burning Mountains; after such infinite numbers of culinary, furnace, and workhouse Fires; and, after all, the devastations that have happened since the invention of Fire-Arms: I say, after all these extraordinary methods of producing Fire, there does not appear to be the least quantity more at present, than there was in former ages. And I'll almost venture to promise, that our following examination of the *Pabulum* of Fire, will make it appear beyond contradiction, that the case is here very different from what people generally imagine. Let us therefore set about this very useful, and agreeable inquiry; and in the first place let us consider combustible matter as we find it, in the Vegetable, Animal, and Fossil Kingdoms. Now here we shall come at its Nature more readily, if we first examine it in the class of Vegetables; for 'tis by these that Animals are nourished and supported; and these may more easily be examined, and understood, than Fossils.

This scarcely
credibly.

The *Pabu-
lum* of Fire
in Vegeta-
bles.

An exami-
nation into
that part of
those that
feed Fire.

All Vegetables that we are hitherto acquainted with may be burnt with Fire, and will feed the Fire whilst they are burning; the Larch-tree itself not excepted. But as these now may be exposed to Fire, either crude, whilst they are yet perfectly alive and full of green juices, or when they are dead, and dry; hence they ought to be considered in both these circumstances: And as a right knowledge of the green ones, will help us more easily to conceive of the dry ones, for this reason, a proper regard to method leads us to examine what it is, that is properly combustible in Vegetables whilst they are alive.

All crude Vegetables, therefore, of what kind soever, contain in them, Water; Spirits, as they are called, or invisible exhaling Corpuscles, which are generally odorous, and for the most part reside in this Water, and are dispersed into the Air as soon as ever separated from it; an acid volatile Salt, which almost always appears in a liquid form; a volatile alkaline Salt; a light volatile Oil, which has generally the peculiar scent of the Plant; a more fixed, heavy Oil; a black Coal, which tho' it is forced with a strong, and long continued Fire, in a close vessel, yet continues fix'd, and black; white Ashes, which are the remains of this black Coal, when it has been burnt in an open Fire; a fix'd alkaline Salt, which is contained in these Ashes, and may be procured from them, by making a *Lixivium* with them; and lastly, another part of these Ashes which remains after this Salt, is separated, and is called pure Earth. This, Gentlemen, is an exact account of those parts that have been discovered in combustible Vegetables. In these, therefore, as they are changed by the various actions of the Fire, we must examine what part it is, that is in reality inflammable, or combustible.

If crude Vegetables then, containing all the parts abovementioned, are committed

mitted to a brisk Fire, whilst their Moisture is yet in them, the first thing they yield is a Smoke, or vapour, which ascends in the appearance of a Cloud, and may be collected in form of Water, either acid, or alkaline, according to the nature of the Plant, the proper scent of which, in some measure, it almost always carries along with it. This Vapour is light, thin, and almost pellucid.

A particular account of what happens; First, in a green Plant.

After Vegetables have been deprived of this first part by the Fire, and, hence, begin to grow dry, then another kind of Smoke begins to arise, which is generally black, thicker, acrid, opaque, dense, and fetid; which every moment grows thicker, and denser, till at length it becomes of a pitchy blackness, and is rolled up, and whirled pretty strongly about the Vegetable.

Not long after this there bursts out a brisk, lucid, crackling Flame, and succeeds this thick Smoke; for this ceases when the Flame appears, and there always remains so much the less of it, as the Flame burns more clearly: But if you extinguish this Flame, then this dense black Smoke soon appears again. If this liquid, volatile Smoke now, is caught upon any Body, and by that means condensed; then wherever it fixes, it will form a very black, pinguious, and tenacious Pigment, which is bitter, and fetid, and goes by the name of Soot.

Vegetables being in this manner consumed by Fire, into Smoke, Flame, and Soot, there remains another part at the bottom, which may be made red hot indeed, in the same manner as Metals, but is absolutely unfit to feed, and support Fire; and this is called, Ashes. These now are found to be different according to the different nature of the Vegetables that were burnt: For if the Smoke they emit when they are exposed to the Fire, is of a very volatile, acrid, saline, and alkaline nature, then the Ashes that are left are for the generality insipid; as appears, in Garlic, Onions, Scurvy-grass, Rocketts, Hedge-mustard, Cresses, Leeks, Water-mint, Mustard, Mithridate-mustard, and the like acrid antiscorbutic Plants, which when they are burnt yield scarcely any fixt Salt. On the other hand if the Plants are succulent, and acid, and their fumes are so likewise, there then remains a great deal of Salt in their Ashes; as we find in the green branches of almost all Trees, which if they are large when they are laid on the Fire, there distils from their ends, an acid Water in great quantity. And lastly, if the Vegetables are of the austere-acid, or the aromatic-bitter kind, then the Ashes of these too yields a Salt in great abundance.

If Vegetables are moderately dry, and their Water is exhaled when they are exposed to the Fire, but yet are not too old; in this case the very same things happen as in the former, and in the same order, but there will be a much smaller quantity of the first watery Vapour.

In a dry one.

If the Vegetables are worm-eaten, fungous, light, very dry, and very old; then if they are laid on the Fire, they will hardly burn with such an open Flame but will grow red hot, shine, continue lucid some time, and then moulder into Ashes, in which there will be hardly any Salt at all; nor will they scarcely yield any Smoke, or Soot.

In a very dry one.

Since, therefore, these things that we have mentioned hold true in every kind of Vegetable that is burnt, we may hence upon inquiry be able to discover, which of all these parts it is that is in reality properly combustible.

First then, let us examine the Water which constitutes a considerable part of every kind of Vegetable. And this we find is capable of admitting, and retaining

An examination of the particulars here. First, of the Water.

retaining for some time any quantity of Fire, not exceeding 212 degrees or a little more, but then, the Elements of the Water have received such a disposition from the Fire, that no more can be disposed, and confined in it. Hence, therefore, it is not possible by any known Art whatever so to impregnate Water with Fire, as to make it put on the brightness of a red hot Body, and thus to become perfectly lucid. Nay if Water, whether hot, or cold, is thrown in large quantity upon a burning flame, or any kind of matter that is on Fire, it will immediately reduce that violent Fire to 212 degrees, and by this means stops every kind of Fire, takes away the redness from Bodies that are heated, and extinguishes flame. Nay, if by the action of Fire, Water is resolved into Vapours, that are very active, and expand themselves every way with a great deal of force, yet even then, when it is reduced into this form, it has the very same effects with respect to Fire. This is evident; for if you hold a live-coal, or lighted Torch in the densest steam of boiling Water, it will be perfectly extinguished as if you threw Water upon it. And our chemical distillations likewise demonstrate, that Water, exert what force of Fire you will upon it, will always retain every character of pure Water. In the mean time, however, I cannot deny but that there are a great many effects produced by the Water in the burning of Vegetables, that would not otherwise happen: For if you fling Water upon Oil, whilst it is boiling hot upon the Fire, there will arise a new action betwixt the Fire, Water, and Oil, very different from what would have happened had not this been done. Suppose a pound of Oil, for instance, actually boiling, and on flame in a copper vessel, the Fire then in this Oil will have 600 degrees of Heat; but it will keep within bounds so long as it is moved equably through the Oil, and disposes it into a bright flame: Let now an ounce of Water be thrown at once into this Oil, whilst it is thus boiling, and flaming, and there will be immediately produced a rumbling, crackling noise, the mixture will fly about in a surprizing manner, and the motion of the whole will grow perfectly unequal: For the Water as it falls by its own weight through the Pores of the boiling Oil, meets every where with a degree of Heat three times greater than that of the hottest Water, whence the Elements of the Water being expanded with a prodigious force, and agitated with an exceeding swiftness, they put the more tenacious particles of the Oil into motion, dissipate them, and carry them with them into the Air. If whilst Bodies are burning, therefore, any Oil, and Water happen to meet in them, the Fire that is excited will be very different from what it would be otherwise: And this your Smiths are well acquainted with, who when they have a mind to blow up a very brisk Fire generally sprinkle a little Water upon their Coals. But there is another circumstance too in this affair that ought to be taken notice of, and that is, that Water is capable of receiving a greater quantity of Fire when it is compressed by a greater weight of the Atmosphere: And indeed this augmentation is so considerable, that for every increase of this weight there is a sensible addition of a degree of Heat. Hence, therefore, should it ever be so confined within Bodies on fire, as to be compressed with a double Atmosphere, what a terrible explosive force would it hereby acquire? And from this consideration I have often thought, and not without astonishment, how vastly the quantity of Fire that may be communicated to Water, would be increased, should the

Water.

Water be placed in the Center of the Earth. For Air at the depth of 409640 fathoms from the surface of the Earth would be as heavy as Gold, according to *Mariotte's* Calculation, if the law he supposes always holds good: With what force then must Water be compressed in the same place? And of consequence how much more Fire would it be there capable of receiving? Would not Water, if it was made to boil strongly there, shine as much as Metals that are made ever so hot? Certainly this appears more than probable. Compare *Hist. de l'Acad. Roy. des Sc.* 1703. 6. and *Mem.* p. 101. But again, there is yet another power of Water, when in the Fire, that is very particular and surprizing. If you melt, for instance, a fixed alkaline Salt with a strong Fire in a Crucible till it runs like Water, and then instantly pour it out into an iron or copper mortar, if there is ever so little Water at the bottom of the vessel, it will be so agitated in a moment by this excessive Heat, as to be able to make the Salt fly about with an incredible *impetus*; as the Chemists have often experienced to their great loss, and danger. But the effect of Water with respect to Fire is never more violent, or terrible, than when it happens to meet with melted Brass: For if whilst this Metal is in fusion in the large melting Furnaces, a little Water unfortunately falls among it, there arises immediately a terrible noise with so violent an explosion, that the strongest Furnaces are instantly tore to pieces. If a few grains of melted Brass are thrown into Water, the force thus produced likewise is so prodigious, that it will burst the strongest vessel asunder, and reduce it to powder in an instant. *Hist. de l'Acad. Roy. des Sc.* 1699, p. 110. Hence, therefore, it appears, what are the effects of that Water which naturally resides in combustible Vegetables, with regard to the Fire that is burning them, if you consider it separately as Water; and how much it is capable of increasing the force of Fire, if it happens to meet with Oils, Salts, or Metals: So that the same Body, that is looked upon as peculiarly proper to extinguish Fire, we see, may under some particular circumstances, be the greatest instrument of rendering its power more intense.

The Spirits, then, as they are called, of Vegetables, come next under consideration, and that, as they naturally swim in this Water, and float about with it, before the Vegetables have undergone any degree of fermentation. And these, though you take ever so much pains to separate them from the Water, and collect them pure together, are never found to contain any thing in them that will feed, and support flame, or Fire. On the contrary, let them be depurated ever so nicely if you throw them upon the Fire, they will soon put it out, in case they have no mixture of Oil in them. The very fragrant Water that exhales from green Rosemary when it is chemically managed, has nothing in it inflammable. Nay, if with a very gentle Fire you separate the most fragrant part of this again in a close vessel, neither was this ever found to yield a proper *Pabulum* for Fire, but on the contrary it extinguishes it when it is burning.

Secondly, of the native Spirits.

The third sort of Bodies, that enter into the composition of Vegetables, are what the Chemists call acid Salts, which exhale too with the scented Water, and Spirits abovementioned. These volatile Salts, now, have long ago been discovered to be very often exceedingly acid, as the smoke that arises from acid Wood when it is burnt demonstrates, as well as the acid Soot that is sometimes.

Thirdly, of the acid volatile Salts.

sometimes produced by it. Nay, the Spirits that arise in the distillation of the very heavy Woods, such as Box, Juniper, *Guaiaicum*, Oak, and the like, are found to be as acid as Vinegar itself. Thus if you take shavings of *Guaiaicum*, and distill them with a moderate Fire in a very clean vessel, you will have a liquor, that by every characteristic discovers itself to be very acid. If you then carefully separate it from all the Oil that is mixed with it, which may be easily done, by filtration, and gentle distillation, you will by this means have your Acid perfectly pure, limpid as Water, and even then considerably volatile: And yet, when it is by this management rendered as pure as possible, if you throw it upon flame, or Fire, it is so far from supplying them with fuel, that it will soon extinguish them. Nay, and that pure acid, vegetable Spirit, that is procured by Fire from the native Balsams of Vegetables, is perfectly of the same nature. If with an exact Fire you distill some pounds of fine Turpentine, in a very clean vessel, you may draw from this oily, pinguious Balsam, a liquor of a perfect acid taste, that may be intimately mixt with Water, and is perhaps the noblest diuretic we are acquainted with; and yet this, which possibly you would not imagine, will extinguish Fire in the same manner as common Water does. We evidently see, therefore, from these Experiments, that the volatile, acid Salt that rises from Vegetables when they are burnt, is not a proper fuel for flame, or Fire, but on the contrary put them out. But here, perhaps, you will be ready to say, don't we see plainly, however, that Sulphur will burn? Certainly it will. But, you'll go on, Sulphur is compounded of a fossil Acid of Vitriol, Alum, or the Pyrites, united with a vegetable, or fossil Oil. And this is generally true. Hence, then, you'll be apt to infer, that the latent Acid of the Sulphur is a proper *Pabulum* for Fire. But, Gentlemen, if we will but look into this affair with proper care we shall find that it is the Oil only that in this case feeds, and supports the Fire; for the Acid does not remain in the flame, but is dissipated in fumes, which being afterwards collected, compose that liquor which goes by the name of the *Oleum*, or *Spiritus Sulphuris per Campanam*, and is the true original Acid of the Sulphur without any alteration.

Fourthly,
of the volatile Alkali.

But again, if we examine the volatile, alkaline Salts, that exhale from most kind of Vegetables whilst they are burning, and are found to be contained in their Soot; or that are procured from some of them purely by distillation, as we see in Garlic, Onions, Scurvey-Grass, Rockets, Cresses, Leeks, Horseradish, Mustard, Mithridate-mustard, and others: I say these Salts, if they are carefully separated from the Water, Spirits, and acid Salt beforementioned, are never observed to burn, or flame in the Fire, but either fly off immediately, or diminish its power. And lastly, even that volatile alkaline Salt, that is artificially produced from putrified Vegetables, which is in larger quantity, and more acrid than the former, appears by no effect whatever to be a proper *Pabulum* of Fire. Give me leave, however, here to give you this caution, that what I assert of these Salts, must be understood of them, when they are reduced to their greatest purity, so that there is not the least Oil adhering to them. For in the distillation of Vegetables, as well as in the burning of them, when the saline, alkaline, volatile part rises, it carries up with it a considerable quantity of a fetid, volatile Oil, which it pretty intimately unites with itself, so that a person may easily be deceived if he makes this Experiment with

with the Salt, whilst this Oil remains mixed with it; for then if it's exposed to the Fire it will really burn. But as soon as ever this Salt is perfectly freed from its Oil by the methods which we shall hereafter explain, and is by this means rendered quite pure, then its inflammable power is intirely taken away.

The fifth part that enters into the composition of Vegetables, is the Oil ^{Fifthly, of the Oil.} that's procured from them by distilling them with boiling Water in a close Alembic; and this is called their essential Oil, and is the most volatile of all the Oils that are drawn from them, as well as the most pure, not having so great a mixture of heterogeneous parts with it, as the rest have. If this Oil, when it is well separated from all the other parts, is set upon the Fire, in a clean vessel, and suffered there to grow hot, and boil, and then a Flame is apply'd to it, it will take fire, flame, burn away, emit a little Smoke, consume and leave behind it a few *Fæces*, that are of the nature of Coal, black, spungy, brittle, and earthy. If this very Oil now, which is generally reckoned so pure, undergoes a second distillation in boiling Water, it then becomes a great deal purer, thinner, and lighter than it was before, and leaves behind it a good deal of new *Fæces*, that will not rise in this second operation: And if you then take this Oil thus rectify'd, as the Artists call it, and expose it to the Fire in the very same manner as you did the former, it will take fire, yield less smoke whilst it is burning, and the quantity of the *Fæces* that are left behind, will be a great deal less than before. And as for those that remain in the Water after this second distillation, they are nothing near so combustible as this rectify'd Oil. Hence, therefore, it appears, that the inflammable matter is by this means diminished, but at the same time, that part of it which remains, becomes much more disposed to feed and support Fire. If the purification now of this Oil by distilling it in boiling Water, is frequently repeated, then at last, a large quantity of this Oil, that was at first look'd upon as inflammable, will appear to be of an earthy Nature, that will not so easily burn in the Fire: In the mean time, however, the Oil that rises in distillation, and is separated from the new *Fæces*, grows every time lighter, finer, and more limpid, burns away with a clear Flame, generates less Smoke, and leaves behind it less *Fæces*, than it did in any preceding operation. And this may be prosecuted so long, till this Oil becomes so vastly subtil, that it will at last almost consume without any Smoke or *Fæces* at all. But again, if you take this distill'd Oil after it has by this means been rendered totally inflammable, and put it fresh into a clean glass Retort, and with a gentle Fire gradually increased, carefully distill it again, and repeat this frequently as before; then, as the famous Boyle has taught us, the greatest part of this Oil will be changed into earthy *Fæces*, that are left at the bottom, and are not very combustible; but the Oil that still remains, becomes every distillation, purer, and more inflammable, so that it burns away in form of Flame, without any considerable Smoke or *Fæces*. If then all the *Fæces* that are left behind after every distillation are collected together, and torrify'd, and made red in an open pure vessel, they'll emit Sparks, and Smoke, and sometimes Flame, and at last will moulder away into Ashes that are absolutely incombustible. These Experiments now, Gentlemen, I beg you will consider very carefully: For hence we may already discover, how small a portion of this Oil, when purest of all, truly burns away in Flame, without
Smoke

Smoke or *Fæces*, that is, is totally and perfectly combustible. And this will be of singular service in helping us to an accurate knowledge of the nature of Fire, considered as it acts upon this its *Pabulum*, and as it is likewise affected by it. This then being rightly understood, please to give your attention to an Experiment of another kind. Observe this live Coal, which as you see, is very full of Fire: I'll put this now into this copper Vessel, and pour upon it this cold ætherial Oil of Turpentine, which of all Oils is esteem'd the most inflammable; and you see, contrary 'tis probable to your expectation, that this red Coal is as soon extinguished with a Smoke and Hiss, as if it had been immersed in Water. So that hence it appears, that Oil is not so soon lighted by a live Fire as people generally imagine; but in order to this, there are some particular circumstances requisite in the application of them to one another. It is very likely you may imagine, that Flame is necessary to set it on Fire. To try then, whether this is the case or no, I have disposed a Candle as you see in this vessel, in such a manner, that the extremity of the Flame is below the brim; and hence, if the vessel is fill'd with Oil, the Flame will be below the surface; I'll pour in now the same pure distill'd Oil of Turpentine till the Flame is cover'd, and you see it is perfectly extinguish'd, nor does the Oil take Fire. But again, I have heated some of the same Oil in another vessel, till it smokes and is ready to boil, into which you shall see me throw this little glowing Coal: Don't you all now certainly expect that I shall set it on fire? Nothing less; but it sinks as you perceive with a noise, and goes out. And lastly, I'll invert this burning Candle, and thrust it into the same almost boiling Oil; and here again you see that it is perfectly extinguish'd without lighting the Oil, or being lighted by it, contrary to what one would imagine. But those vegetable Oils remain still to be examined that are drawn from them by distillation, without the addition of Water, which have a fetid empyreumatical scent, are opaque, and of a thicker consistence. These now, if they are managed in the same manner as the distill'd Oils abovementioned, exhibit exactly the very same *Phænomena*. At first they are inflammable, burn away, emit a great quantity of black Smoke, and leave behind them a great deal of *Fæces*; but afterwards, by repeated distillations, they become purer, lighter, more limpid, more inflammable, yield less Smoke, and leave fewer *Fæces*, and every operation are depurated more and more, and grow more combustible. And when by this means they are rendered like the essential Oils, they are perfectly affected by Fire in the same manner. Since then all these things are constantly observ'd to hold true in every vegetable Oil, existing in what condition soever; whether it is naturally concreted in some parts, or naturally secreted in others, as Gums, Balsams, Resin, and Pitch; or procured by distilling the Vegetables; or lastly, by burning them: I say, since what we have said holds good of them all, we may hence form a true notion of the matter that is chiefly combustible, and hence be able to draw a great many inferences that are absolutely necessary to a just History of Fire; and which indeed, if we are not first well acquainted with, we shall certainly run into a great many errors, if we pretend to explain either the nature of Fire, or combustible Matter. If we rightly understand now, what has been laid down concerning that part of Vegetables, which alone, is really burnt when they are set on fire, *viz.* their Oil, or as it is call'd, their Sulphur, we shall then be able hereafter to proceed more

more readily in the rest: This therefore I recommend to your careful consideration, as it will be of service to us in our future inquiries.

If any kind of Vegetables are burnt in the Fire to such a degree, as to be glowing red quite through, but are not yet reduced to Ashes, then, if they are on a sudden suffocated in close Air, extinguished with Water, or buried deep under Ashes, or any other Bodies that exactly cover them, they lose their Fire, and are changed into a Body that is perfectly black, after you have shook off the Ashes that may possibly lie upon their outward Surface; and the Body thus prepared is called a Coal. Again, if you take any sort of Vegetable whatever, put it into a metal, earthen, or glass Receiver, and with a violent and long continued Fire, urge it so long till scarce any thing more will come over into the Receiver; then, if the vessels were so perfectly closed that not the least Air could find admittance, there will remain at the bottom of the Retort, a Vegetable substance intirely black, which is likewise a true Coal, exactly of the same nature with the former. Now either of these, if it is laid upon the Fire when it is thoroughly dry, very readily takes fire, retains it strongly when it's once kindled, burns as long as any blackness remains in it, and thus almost totally consumes without any Smoke: during all this time, however, it emits an exhalation, which if received into a close place, quickly, and insensibly, proves fatal to every kind of Animal; nor does it at all signify, whether the Coal is prepared from Plants, Woods, or bituminous Turfs. When every thing then, that was black in the Coal is thus consumed by the Fire, what remains is a whitish Powder, which goes by the name of Ashes, and which it is impossible to excite into a Flame by the application of any degree of Fire whatsoever: The most you can do with them, is uniting Fire with them in the same manner, as you may with Metals, Stones, and the like, which we gave an account of before in our History of Bodies, that are capable of retaining Fire without being consumed. In this affair now, it is particularly remarkable, that the Coal then only grows unfit to feed the Fire, when it changes its black Colour for this cineritious one, it constantly affording a *Pabulum*, so long as the former remains. This we see evidently in that common, yet elegant Experiment made with that exceeding fine vegetable Coal, Paper, when burnt to a blackness: For if a Spark falls upon such a black Paper, it soon begins to run up and down in form of a fiery Spark, and leaving those places that are whitish, and will no longer burn, it perpetually shifts about to those that are black, which it in like manner consumes, and then quits for the next black Spot, till at last by this means, all the blackness being perfectly destroyed, there remains the form of a very thin Paper, consisting purely of white Ashes, which in some measure still cohere together. A vegetable Coal, therefore, is that part of Vegetables, from which the Fire has expell'd the Water, Spirits, volatile Salts, and some of the lighter Oil that is not so closely united with the other parts; and in which there still remains an Earth, and fix'd Salt, whose increased Surfaces the Fire has covered over with a rarified attenuated Oil, which by burning has acquired a black Colour: For all that appears black in the Coal is purely Oil, which being put into a rapid motion, and greatly expanded by the action of the Fire, was in some measure extricated from those parts that were not inflammable, tho' not perfectly freed from them, and hence being nearest to the Flame, and attracted towards the Surface, upon this sudden extinction, it remained apply'd

Sixthly, of
the Coal.

A a

to

to the exterior *Superfices* of those little cells, in which the Water, Spirits, and volatile Salts resided before the Coal was thus prepared. From what has been observed then, we may at last conclude, that the combustibility of Coal, consists intirely in the Oil that remains united with it, the other parts being by no means capable of flaming or burning so as to be consumed by the Fire that is received into them, as those Bodies are, which are a proper fuel for Fire.

Seventhly,
of the Ashes.

But not to omit any thing this is requisite to make this History fair and compleat, let us yet farther examine these very Ashes that remain, after Vegetables are thoroughly burnt. These now, if they are produced from pure Vegetables, will be almost always of a pretty white colour, and a salt taste, a few as I hinted before excepted. If you boil these Ashes in Water in a clean vessel, the *Lixivium* will have an acrid, alkaline, fiery, urinous taste. If you, then, pour off the Water that is thus impregnated, and add more fresh Water to the remaining Ashes, boil this again as before, then pour off this, and put on more, and repeat this operation, till at last the Water that is thus boiled with the Ashes comes off as insipid as it was poured on; then, if you mix all these *Lixiviums* together, and evaporate them to a dryness, you will always have at the bottom of the vessel an acrid, alkaline, fiery, fix'd Salt: This now will grow perfectly red hot in a strong Fire, and retain a lucid Fire in it for some time, but will never support Fire, excite Flame, or be itself consumed by them as a proper *Pabulum*. Fix'd alkaline Salts therefore are incombustible; as Stones, &c.

The Salt of
which is not
a proper *Pa-
bulum* of
Fire;

But let us now look back to that part of the Ashes, which after the separation of all the Salt, remains at the bottom of the Water; and this, if it is carefully dry'd, and kept perfectly by itself, is found to be a light white Earth, vastly simple, and exceedingly immutable by the action of the Fire: This evidently appears in the Cupels, which are made of these Ashes, with the addition only of Water; for these, when they are exposed for a long time, to a very intense Heat, grow red hot as other incombustible Solids do, but the Earth itself will never burn, flame, or supply the Fire with a proper *Pabulum*.

Nor their
Earth.

Eighthly,
of the
Smoke.

Thus, then, we begin by degrees to discover what parts of Vegetables it really is, that properly feeds, and supports Flame, and Fire, and which must necessarily remain in the Fire so long as it continues to flame, or burn. But farther, whilst Vegetables are thus on fire, there constantly rises from them a dense Smoke, which at first is watery and thin, grows thicker and thicker every moment, at last grows very black and dense, and then is blackest and densest of all, when the Flame is just appearing, which generally soon breaks forth with a crackling noise; and as soon as ever the Flame appears, the Smoke immediately diminishes, and so much the more, as the Flame is more vivid; so that when it is brightest of all, the Smoke seems quite to cease rising, tho' even then, indeed, we are sure that there is actually Smoke. Hence, therefore, it seems probable, that Smoke is a confused mixture of different parts of the vegetable *Pabulum* of Fire, which are put into a violent motion by the action of the Fire, are carried upwards, and agitated among one another, but not thoroughly set on fire: If this action, however, is continued, and increased, and these Particles are urg'd with a stronger Fire, they then grow red hot in the Air, the Smoke is converted into Flame, and the Particles of the Smoke being now grown bright, and at the same time vastly attenuated, appear purely igneous.

And

And hence, likewise, it is evident, why a vivid Flame, when it encompasses the whole burning matter, seems to consume all the inferior Particles that are agitated by the Fire, in the form of Flame, without any Smoke; for it is certain, that except the watery part, Smoke may be totally changed into Flame. This, indeed, has long ago appeared to be true, by that elegant Experiment of the *Focus Acapnos*; in which, one may evidently see, that the black Smoke which rises from burning Vegetables, is in reality a Coal, which is combustible in a strong Fire, or great Flame: For when it is exposed to either, it is reduced to mere Ashes, or its matter is so far attenuated, that it escapes our senses, and is dissipated into the Air.

Which is a
volatile Coal.

The Inventor of this Instrument was that ingenious Artist *Dalesmius*, who contrived it in the Year 1686 at *Paris*, as we have an account in the 116th Page of the *Journal des Scavans*, published that year. The famous *Justeleus* afterwards first published a Cut of it in the *Philos. Transf.* almost at the same time, which is as follows. ABCD is a hollow Cylinder made of Plates of Iron, open at both ends, within whose inferior Base BD, there is fitted the Grate BD. This Cylinder, which is the Fire-place of the Instrument, is joined to the cylindric Tube EFG, in such a manner, that there is a communication between their Cavities. And this Tube EFG, which is of the same capacity with ABCD, made of the same Metal, and in the same manner, is open at G, and close at E. If then the Tube EFG is made very hot, and some live Coals are laid on the Grate BD, and over them some combustible matter, then the Flame that is produced, will descend into the Tube EF, and pass through FG, and all the Heat will go out at G; and the Smoke likewise that is generated following the same course through the Tube EFG, will be forced to pass through the Flame that fills the whole Tube; and hence, being acted upon by the Fire in all this passage, it will lose the thickness and disposition of Smoke, will be converted into Flame, and in this form passing out of the Aperture G, will disappear, without any visible Smoke, or Soot. The famous *De la Hire* has added some Notes upon this Machine in the place in the Journal above cited. In order now to give you an ocular demonstration of the same thing, I have provided this Instrument which is made of Plates of malleable Iron. ABCDEF, Fig. 2. is a hollow vessel consisting of five equal iron Plates well soldered together, and open only at the top ABCD. At the height EI within this vessel there is a Grate IKLM. In the side DF, there is an elliptic Hole NO, of the breadth MK, and height EI, to which is joined the Tube OGH, open at ON, and H, and every where of the same capacity. Please now to observe the effects of this Machine. On the Grate IK, I lay some live Coals, that the vessel may grow hot; and that the Air in the cavity of the Tube NOGP, may at the same time be heated likewise, I put some more on the part of the Tube NP. As soon as ever now the Air below the Grate, and in the Tube NOGP grows hot, the Heat that was produced by the Coals above the Grate in the vessel CK is diminished; and the Heat in LF below the Grate, and in the Tube NOPG, is in proportion increased; so that now you observe the force of the Fire, with its little Flames, tend downwards, by which means a new degree of Cold is generated above the Coals that are laid on the Grate. The Machine then being thus prepared, when I lay this Straw upon the Coals, you see with what rapidity the Flame drives downwards through the Grate, and

A Fire-place
and Chim-
ney without
Smoke, the
Smoke being
burnt.
Pl. IV.
Fig. 1.

Fig. 2.

through all the Tube OGH, so that it breaks out at the top H, without Smoke, and there produces a very great degree of Heat; whilst at the same time the space CK continues cold. But farther, whilst I add Wood, Turf, Sulphur, and Oils, it proceeds exactly in the same manner, and the force of the Fire is so great within the Tube, that the Tube you see is now red hot, and the Fire burns with so much fury and rapidity, that one may hear the noise that is produced by the agitation of the Flame. You take notice too, at the same time, that these Bodies, which commonly, when they are burnt, diffuse an intolerable fetid, or a very agreeable scent, now they are laid on this Fire, don't discover any smell at all, but perfectly consume without the least sign of it, leaving nothing behind them but pure Ashes at the bottom of the vessel under the Grate. All the other parts are driven by the force of the Air pressing upon the Aperture of the Fire-place, into the Tube which is higher, and narrower than the Vessel that contains the Fire; so that all the Flame, and the power of the Fire, exerts itself within the space LFOGH; and hence, the combustible parts that are reduced into a very dense Smoke by the action of Fire, are now carried through this pure Flame, and not into the open Air; by which means, being thus strongly agitated by the violence of the Fire, even within the Fire itself, they are so attenuated in their passage, that every part of them that was combustible, or could be so divided by the motion of the Fire as to become perfectly imperceptible, is dissipated into the Air, without discovering the least sign of any particular quality. Smoke therefore is combustible matter, exceedingly agitated, but not yet shining, or red hot; Flame is the very same matter, only thoroughly red with heat, and divided into very minute Particles. But it appears likewise by other Experiments that Smoke is inflammable. If you take, for instance, shavings of *Guaiacum*, and with a strong Fire force it out of a Retort in a dense Smoke, then, in the end of the operation when nothing rises by the action of the Fire but a very attenuated and rarefy'd Oil, if this Smoke insinuates itself through the cracks of the Lute, and a Candle is apply'd to it, it immediately takes fire, and flames, and that not without a great deal of danger. And the same thing is true of all parts of Animals, if they are treated in the same manner. Hence, therefore, Smoke comes nearest to Flame, and the blacker it is, it comes so much the nearer; for then it becomes a true Coal, exceedingly thin and attenuated, perfectly volatile, and easily combustible; as any one may easily understand from the History of Coal, that has been already delivered. And hence, therefore, lastly, there is nothing in Smoke that supplies Fire with any *Pabulum*, except the Oil; but this will appear more evident hereafter.

Lastly, of
the Soot.

In the last place, in the burning of combustible vegetable Matter, the Smoke which is carried upwards applying itself to the sides of the Chimney, instills into them a penetrating black pinguious moisture, changes them of a very black colour, and fastens to their outside in form of black, loose flocks, that easily drop off; and the matter thus collected is called Soot. This now is in reality a true volatile Coal, but exceeding fat, and hence if it is dry, it is very easily inflammable. It is excessive bitter like Oil that is burnt; very pinguious from the quantity of Oil it contains; and from this Oil's being burnt, is very black, as all other Coals are. This matter now, tho' it appears thus simple, if it is nicely resolved into its parts by a chemical distillation, in the first place yields a
Water,

Water, in pretty great plenty, which being carefully separated and collected, extinguishes both Flame and Fire. And the very watery Vapour that thus exhales in this first distillation puts out Fire intirely; so that you can scarcely properly call it a Spirit. If you then increase your Fire, there comes over from this Soot, a large quantity of yellow, inflammable Oil, which yields a plentiful *pabulum* to Fire and feeds and supports Flame. That part likewise of this Oil which is exceeding subtil, and goes by the name of a Spirit, is in the same manner inflammable. But it farther yields, too, a very volatile Salt, one less volatile, and then one that is drier; from all which if you perfectly separate the Oil and Spirits, just mentioned, you will find nothing at all in them that is any ways inflammable, but only a Salt that is incombustible. And last of all, this *analysis* will give you a Coal, which we have sufficiently considered already, under our sixth and eighth Observation. Hence therefore it appears, what Soot is, and what part of it is really combustible. If this Soot now is taken dry from the Chimney, and thus laid on the Fire, it burns fiercely, and breaks out into Flame, in the same manner as any other combustible matter does; which persons experience, sometimes, to their great danger, when they let their Chimneys go too long without sweeping; for the Soot being, by this means, collected in large quantities, frequently takes fire, and flames out of the top of the Chimney.

From all these Observations, then, that I have fairly related to you, we plainly perceive, what part of crude Vegetable it is that is properly inflammable, and may be esteemed a true *Pabulum* of Fire, viz. the Oil alone, and that, in what form soever it exists, whether in a thick one, or a thin one, like that of Spirits.

Conclusion
concerning
the crude
Pabulum of
Fire.

Since every thing, however, must be considered and examined that will give us any light into the nature of Fire, and that it may be perfectly evident, what it is in Vegetables that properly and solely yields a matter proper for the nourishment of Fire, let us now suppose, that we certainly knew, from what has been premised, that there is nothing contained in crude Vegetables that will feed and support Fire, and is, at the same time, capable of being dissolved in Water. But if we will turn our speculations farther, to the vegetable Substances, that, by a true chemical fermentation, are produced from those Vegetables that are thus disposed to ferment, we shall then find, that by this method a liquor may be produced from them, which goes by the name of Wine; this, now, when it is fined according to Art, and hence rendered pure, if it is thrown upon a large Fire, will soon intirely extinguish it; nor is it any way fit to support Flame. Nay, and after you have examined it in this manner, if you put it into a clean glass vessel, and, with a very gentle Heat, evaporate the most volatile part of it, and reduce it to a Fume; even this, if you apply a Flame to it, will scarcely burn, but on the contrary, for the most part, rather puts it out.

Wine don't
take fire.

But if this Vapour, when it is afterwards grown cold, is collected in form of a liquid, and this is treated in the same manner as the former, then this will yield a liquor that may be mixed with Water, and at the same time will perfectly take fire, will afford a plentiful *Pabulum* to Flame, and be itself consumed in it. That part of the Vegetable, now, that is separated from the Wine, whether in form of Lees, or the *Residuum* in the distillation just mentioned, if it is examined by the fire, will yield almost the same parts, which

But its Spirit
does.

are

are found to be procured from crude Vegetables, under the same management. By this instance therefore it appears, that by Fermentation there is generated from Vegetables, a liquor that will mix with Water, and feed Flame, which did not really exist in them, when they were crude.

Putrefaction
of Vegetables
produces
Fire.

But it will be worth our while to examine Vegetables whilst they are managed in another manner, different from the former. If Vegetables then are thrown into large heaps, when they are just cut down, and full of their natural juices, or are disposed under the same circumstances, in great wooden vessels, close and hard pressed down, they will there grow warm, then very hot, and emit a watery Fume, a disagreeable Smell, a black Smoke, Flame, and Sparks. On the other hand, if they are exposed to air after they are mow'd, till they are grown sufficiently dry, then, though you heap them together in the same manner, they will continue dry, and will not undergo the same alterations: But however, even in this case, if you pour Water upon them, till they are thoroughly moistened, they will conceive Heat, and take fire in the same manner as the green ones just mentioned. After Vegetables, now, have by these means acquired this spontaneous Heat, and retained it for some time; if they grow cold again, without taking fire, they then are found to be quite putrified, and converted into a fetid, pappy Matter. If then you distill this putrified Pulp, the first part that comes over will be a watery Vapour, which will extinguish Fire and Flame: And when this first watery liquor is drawn off, if you expose the remaining dry parts to an open Fire, they will yield almost all the same principles as crude, or fermented Vegetables do in the same circumstances.

But lastly, if you take Vegetables that are perfectly putrified, and distill them in a Glass retort with a moderate Heat, till they are become nearly dry, you will then have first a fetid subpinguious or cloudy Water, in which there is found to be contained a volatile, alkaline Salt, tho' then intirely dissolved; and indeed it is rather from the admixture of this Salt, than from any true Oil that the Liquor appears thus pinguious. Whether now this Water thus impregnated with Oil, is thrown upon the Fire; or whether you first resolve the compound Liquor into a purer Water, and its Salt, and then throw both these separately upon Fire, the Event in both Cases will be exactly the same; for in both the Fire will be extinguished.

And some
inflammable
parts.

But again, when this first Liquor is separated, and the putrified Matter remains now almost dry in the Retort, if you urge the *Residuum* still further with a stronger Fire, there will come over a fluid, oily, thin Liquor, which swims upon Water, is fetid, and yields a *Pabulum* to flame, like Oil, or Spirit of Wine. After this Spirit, or fine Oil, is drawn off, if you still increase your Fire, then a volatile, alkaline Salt, and an Oil thicker than the former will rise together in a considerable quantity. And here again, as the Oil is found to be inflammable, so the Salt appears perfectly otherwise. But farther, if when you have separated all these, you still urge the *Residuum* with a strong Fire, and continue it a good while, you will have another Oil, still thicker, and more tenacious, almost like pitch, which is exceedingly combustible: And at the same time there will come over a dense Vapour, which, upon the Application of a lighted Candle, will instantly take Fire in the open Air. This being done, if the Fire is still constantly kept up to its greatest Degree, you will at last

last force out a *Phosphorus*, which, though it is not of so solid a Form as that which is procured from animal Substances, yet it comes very near it in a great many of its Properties. Last of all, when this fluid Matter is intirely gone off, there is then left in the Retort, a very black Coal, such as we described before, in which there remains indeed a black inflammable Oil, but not the least appearance of any fixed Salt.

If we thoroughly understand then what has been laid down, we may boldly and safely determine, concerning all the parts of Vegetables, naturally contained in them, that are endued with such properties, that if Fire is applied to them, they may be consumed into Flame, and will so long feed and continue Fire in that place; as likewise of those which may by certain methods be procured from them, or produced in them, so as to dispose them to have the same effect. It is evident then, that amongst these Parts, the Water, the native Spirits, as they are called, all the kinds of Salts, and the Earth of Vegetables, are capable of being heated by Fire, and hence of admitting Fire into them, and of retaining and preserving it there for a considerable time, but this only under the limitations above mentioned. The Fire likewise, when it is thus united with them, may, by the help of them, be at pleasure communicated to other Bodies: And the fixed Salts may, by a strong Fire, be heated thoroughly red hot, and will retain this shining Heat a considerable while. In the mean time however, neither of these four Parts can, by any contrivance whatever, be raised into Flame, or, by the application of Fire, be consumed in it, in the same manner as those Bodies are which are generally called the *Pabulum* of Fire. But farther, the Oils of Plants of what kind soever, their Balsams, the Gums that are generated in them, the Resins likewise, and the Substances compounded of these two last together, hence called Gummy-resins; these five other sorts of Parts, I say, that are found in Vegetables, are disposed likewise to grow hot with Fire, to retain it a great while, to apply it to other Bodies, and that without taking Fire, or flaming themselves; though if you urge them with a stronger Fire, they will melt, boil, and yield a true *Pabulum* to Flame or Fire. But yet even in this case, their Inflammability is only confined to those particular parts of them that are of an oily nature; for all the rest are chiefly of an earthy disposition, and are only acted upon in the same manner as the former which we just described.

Conclusion
concerning
all that is
combustible
in Vegeta-
bles.

But the vegetable Spirits now that are generated by Fermentation; the other Oils that are drawn from fermented Vegetables; and lastly, the Spirits and Oil that are procured from Vegetables by putrefaction; all these, I say, considered as they are perfectly pure Spirits, or Oil, are constantly observed to be absolutely inflammable. It evidently appears therefore, from every kind of experiment, that the Oils of Vegetables, in what Form soever they exist, are the only Matter contained in Vegetables, that without the addition of the other Parts is capable of being so agitated by Fire, as by its assistance to produce true Flame, and then to support and continue it so long as any of these oily particles still remain: That in the mean time this very Matter is by degrees consumed by the Flame, and disappears; and that then too the Flame immediately goes out. And though this Oil is found in Vegetables to have very different appearances, and undergoes considerable alterations from various causes; nevertheless, in the sense above explained, so long as it re-

mains Oil, it will always continue to be inflammable. And yet farther, when by Fermentation or Putrefaction this Oil is so attenuated as to be reduced to very subtil Spirits, that will bear to be diluted with Water; even these Spirits likewise are intirely inflammable, and as a *Pabulum* of Fire have the very same effect which we just now observed of real Oil. But whenever now you have perfectly extracted every thing that is of an oily nature, either from the whole Vegetable, or from any of its parts, then the remainder, treat it in whatsoever method you will, can never be made susceptible of Flame, or capable of supplying it with any nourishment. In the mean while, however, the watery, spirituous, saline, and earthy parts, as they contain and confine these Oils within them, must necessarily, when the Oil is set on fire, be agitated, put in motion, vibrate, and very much increase the force of the Fire; for whilst this is supported by the Oil, this violent agitation of all their particles will of consequence excite a prodigious attrition in the very Flame itself; and hence, being thus agitated, they will apply the Fire more forcibly to any other Bodies. And lastly, they serve for a time to defend the Oil itself from being too soon consumed by the Flame, that thus the *Pabulum* of the Fire might not be so quickly destroyed and dissipated as it would be otherwise.

Whoever, therefore, duly considers all these effects, will easily see that the force of a Fire raised by Vegetables, does not depend only upon elementary Fire, and the Oil set on Fire by it, but principally, and most of all, on the other parts that are incombustible, but which at the same time are agitated by the Fire with a vast *impetus* within the sphere of its activity. And for this reason, when elementary Fire acts upon the purest Alcohol, which is the simplest of all combustible matter, it then neither produces such violent effects, nor so much Heat as it does by a ponderous fossil Coal, a great part of which is not inflammable. Nay, even a Torch made of the rich, pinguious wood of the Pine, gives a stronger Fire than its Oil, let it be ever so pure, or be separated ever so carefully from all those parts that are not combustible. And thus we understand the reason of this paradox, that pure Fire, applied to inflammable matter alone, very often produces a less degree of Fire than if the inflammable matter was mixed with something else that was not so. Hence, the wise Author of Nature has no where created any inflammable substance by itself, but always disposed it in the bosom of some other Bodies that are not combustible, that by this means it may be capable of producing greater effects. As the right notion of this now is of very great consequence in our present inquiry, give me leave to explain it to you in the following manner: When a pinguious piece of Wood is laid upon a Fire, the Oil that is contained in it, in conjunction with the Fire, is capable of exciting, and really does excite a Flame. This then being thus produced, plays upon the surface of the Wood, attracts, fires, consumes and converts into new Flame all the Oil that lies open and exposed to its action; and hence the first Flame is supported, and constantly increased, so long as this Oil comes within the sphere of its activity. The Salt in the mean while, and Earth, that are intimately united with this burning Oil, will at the same time be attenuated, and reduced to very minute particles, by the rapidity of the Oil, and will hence be agitated with more violence within the Flame, than even the Oil itself,
and

and suffer as vehement an attrition as any we are acquainted with. This violent attrition then of these particles, that are exceeding hard, and are very forcibly compressed together by the weight of the atmosphere, will of course collect more fire in this place, and thus make it both larger and stronger; and of consequence will still put this Oil in a more rapid motion; which will very easily account for the vivid appearance of the burning Fire. Whilst these things then proceed in this manner, the solid body of the Wood grows hot to its very innermost parts, dissolves, rarifies, expels the elastic parts contained in it with a very great *impetus*, pours out its melted Oils, and by these successive actions continues and maintains the Fire so much the longer. On the other hand now, if exceeding pure Oil only is kindled by the application of Fire, then the tenacious, oily particles alone will be rapidly agitated by the elements of Fire, which being of a softer nature than the Salts, Earth, &c. must necessarily produce less attrition, and a weaker Fire. They will, it is true, burn away faster; but then their *impetus* will be of short continuance, nor will they collect Fire so powerfully, as when they are mixed with something that is not inflammable. And thus I think I have sufficiently explained what is the true *pabulum* that Fire receives from Vegetables.

It will be our business then in the next place, to examine with the utmost attention, what it is that nature is really effecting, whilst this matter which we have described in the Vegetable Kingdom, is so apply'd to Fire, as to feed and support it. And upon this head, certainly, I have not taken a little pains to come at the truth. After considering the affair then in every light, I have discover'd, first, that all those parts of Vegetables, that in conjunction with Fire are capable of exciting a true Flame, are of that nature, that they will bear to be mixed with one another; especially, if there is no heterogeneous mixture with the pure, simple, inflammable Particles. For to come to the matter more closely, Alcohol is the only Body that we are acquainted with, that is absolutely inflammable; but this, let it be prepared from what you will, if it is perfectly pure, may be intimately united with any other sort of simple Alcohol whatever, so that there won't appear the least sign of difference after the mixture. All kinds of Oils, in the same manner, if they are thoroughly depurated, and separated from every thing else, may be intirely mixed together; as appears by every kind of Experiment. I confess, indeed, in some Oils procured from a semi-fossil Matter, as Amber, and the like, as you increase your Fire successively, the Oils that ascend, will lie upon one another in distinct *Strata*, without being mixed together: But you know very well, that these ponderous Oils, that are at last forced out by the strongest degree of Heat, have almost the very melted substance of the Bodies themselves united with them; and besides, I am here treating only of Vegetables. All vegetable Oils, then, are of that nature, that they'll easily bear to be compounded into one liquid concrete, which will scarcely afterwards be found to have any dissimilarity. But again, all kind of Oils, if they are carefully depurated, may be intimately mix'd with pure Alcohol, so that the Fluid that arises from this Mixture will be absolutely homogeneous, all the parts of it appearing perfectly uniform to the nicest Microscopes. But here, I take for granted, that there is not the least drop of Water, either in the Alcohol, or Oil, for otherwise such union could not possibly be expected. But farther, Camphire, which is a solid vegetable

Of the manner in which Fire is fed by this *Pabulum*.

Substance, and totally takes fire, will intirely dissolve, not only in Alcohol, but in every kind of pure Oil likewise. And the other parts of Vegetables that are perfectly inflammable, may in the same manner be mixed with Oils and Alcohol, and always the more intimately, the more they are purely inflammable. In Refins, Balsams, and Gumma-Refins, this is every where found to be the case. And when they are capable of being mixed in this manner, they are observed to be either naturally fluid, or disposed to be rendered so by a small degree of Heat. How easily does Camphire run by a slight action of the Fire? And what a gentle Heat is sufficient to melt Balsams, Colophonies, and Refins? Nay, many of these inflammable substances, are able to withstand the greatest degree of natural Cold that ever was observed, without being frozen, as is evident in Linseed Oil, and a great many others. It is particularly remarkable now, that all these Bodies that are purely inflammable, whether separate, or compounded together, by their tenacity constantly discover a viscid cohesion of their Particles, which does not a little resist their separation. Observe, for instance, this Alcohol, which of all known Liquids is the most subtil. Don't you perceive, that even the Particles of this run down in spiral *striae*, which cohere and hang together? If you pour Alcohol into clear Water, you observe that the Particles of the Alcohol affecting this cohesion run about in the Water in form, as it were, of little Eels, and by their convolutions sufficiently evince their tenacity: Nay, and even if you dilute Oil with Alcohol, you may discover the same kind of streaks. But it is farther observed, that all Oils that are inflammable, burn so much the easier, the more perfectly, with the less Smoke, and leave the less Ashes behind them, the thinner they are, and the nearer, by their exceeding fineness, they approach to the subtlety of Alcohol; which is every where confirmed by Experiment: But at the same time, the thinner the Oils are, their Flame is always so much the weaker. Thus, Gentlemen, I have laid before you a collection of Observations concerning the nature of the *Pabulum* of Fire, which are constantly found to hold good, and which will help to give us some light into the manner in which Fire acts upon its *Pabulum*, and that again upon Fire. And to this purpose, let us again make use of the following Series of Experiments.

EXPERIMENT I.

The extinction of Fire and Flame by Alcohol.

In this clean, brass, cylindrical Vessel, is contained some very pure cold Alcohol, which of all the Fluids that we know of, is the most totally inflammable; into this, you observe, I dip this Match whilst it is burning; upon which no doubt you imagine the Alcohol will be set on fire: Nothing less; for you see it is perfectly extinguished, all one as if it was immerg'd in pure Water. But again, which is more surprizing, I'll immerge this burning sparkling live Coal just taken from the Fire, in the same Alcohol; and what is the consequence? Why it is extinguished in the same manner as if it had been thrown into cold Water. But now, if I dip the end of this lighted Match, so cautiously into the Alcohol, that some of the burning part, which is of a considerable length, shall be above the surface of the Alcohol, then the attracted Alcohol will begin to take fire, and the Flame will in a little time be dispersed over all its surface.

COROL.

COROL. 1.

Hence, therefore, it evidently appears, that burning Fire will not set fire to the most inflammable matter that we are acquainted with, except in its upper part only that is contiguous with the Air, but will be perfectly extinguished itself, when it is so disposed within the inflammable Body, that no part of it remains in the Air above its Surface. And yet this very remarkable *Phenomenon* is scarcely taken notice of.

COROL. 2.

It is not true, therefore, that active Fire will so easily kindle even those Bodies that are vastly inflammable.

EXPERIMENT II.

I have fill'd the same clean Vessel with very pure Alcohol, which I have heated you see till it emits a Vapour; if I bring now this lighted Match towards this Fume that exhales from the hot Alcohol, as soon as ever the Flame of the Match touches the Vapour, it immediately takes fire, flames, and burns, and the Flame extends itself intirely over the whole surface of the heated Alcohol. And this Flame remains spread accurately over all the surface as a firm *Basis*, nor can by any Art whatever be made to convert into Flame that part of the Alcohol that lies cover'd under its Surface: For all this you perceive it intire, pellucid, not on fire, but remains under the flaming Surface without being consumed, except so much of the Spirits as are separated from it by the Heat, and thus raised and brought to the Surface that is contiguous with the Air; for then these, and no other, immediately take fire and flame; nor is it possible to set on fire more at a time, than those which are now so disposed that they can float in the Air: This I have observed most evidently; for if the Alcohol is cold, and you light it leisurely on its Surface, by dipping a burning Match in it, as I mentioned before, so that some part of the Flame shall still remain above the Surface of the Alcohol; then the Flame that is in this manner excited, will be gentle, weak, and very small. On the other hand, if this Alcohol is first heated, and by this means emits a large quantity of Spirits from its Surface, then the Flame will be greater, and burn with more strength and violence; for then more Particles coming to the Air may be set on fire by the Flame. In this Vessel therefore, the Alcohol will always yield more Flame, the more it is heated through its whole Bulk; and of consequence, if it is made so hot as to boil, then will its Flame be strongest of all. But again, if the agil Vapours that exhale from a Vessel of boiling Alcohol, and float about in the Air, are confined by any means within a narrow compass, then if you bring a burning Candle within this space, thus full of Vapours, the whole place will be instantly filled with a flashing Flame, which shines for a moment with a faint light, and then tends towards the Surface of the Vessel, and fixing there, so covers the exhaling Surface of the Alcohol, that no more Spirits can any longer be dispersed into the former space, or be set on fire there; for now it is all forced to pass through the incumbent Flame, where it is so changed, that during its stay there, it creates Flame itself, but then, is afterwards converted into a Fluid, that is no longer Alcohol.

The preservation of Flame and Fire by Alcohol.

That this is the case, I have abundantly learned from Observation. And farther, this Flame continues to burn so long as there is the least drop of Alcohol left in the Vessel, and then it goes out. All the Alcohol, therefore, can't possibly be consumed by this Flame at once, but only that part of it which forms the Surface contiguous with the Air. The broader therefore the Surface is, the sooner will it be burnt up; and consequently this waste may be increased or lessened at pleasure. Thus then we have two methods of accelerating the Flame, and of consequence the consumption of Alcohol, *viz.* making it boil, and disposing it under a large Surface. This Alcohol now, when it is intirely burnt away, leaves no *Fæces* behind it; nay, if it is perfectly pure, there does not remain the least spot or sign of it: Nor in the Surface of the Flame, is there the least Smoke that the Eye is capable of discerning. Nay, if you hold a very white clean Paper over the burning Flame, it will be no ways soiled with any Soot; but it will receive only a pure Moisture. The olfactory Nerves, however, will perceive a fragrant smell like that of Alcohol. The Flame now of this Alcohol, when it burns in a very quiet Air, is of a conical figure; for the Fire being strongest about the center, elevates the incumbent Atmosphere in that place more powerfully than that does which is towards the circumference of the *Base*, which is less confined and compress'd, and consequently weaker. If you look slightly upon this Flame, you'll take it to be blue; but if you look upon it very intently, the *Base* of it is always blue, but its *Apex* appears double, the inner of which is constantly yellow, but the outer is blue likewise. But there's nothing, it's possible, will seem so surprizing in this Experiment, as what I am going now to shew you. You perceive the Alcohol in this little Vessel burns very fiercely; I'll now throw into it this live Coal which is perfectly red quite through; and you see in sinking it is extinguished immediately, nor is able to retain its Fire when it is cover'd with the Alcohol. What now is the cause of this wonderful effect? Why the live Coal requires a great deal more Fire to keep it burning, than is contained in Alcohol, whilst it is boiling; and Alcohol when it once boils, cannot afterwards acquire a greater degree of Heat. The hotter Coal therefore being flung into this colder Fluid, must of necessity lose that greater Heat, which was requisite to keep it on fire; and therefore it will be extinguish'd or reduc'd to 180 degrees of Heat, which are sufficient to make Alcohol boil, but can never set on fire any sort of combustible matter, that is, can never, by the assistance of the Oil of any such matter, produce a lucid Fire. But farther, as the Coal is totally immersed in the Alcohol; hence it is intirely kept from any communication with the external Air, and for this reason the Coal is not able to set fire to the Alcohol, but only with its first *Impetus* puts the Alcohol into a greater motion, makes it throw out more of its Spirits, and by this means, as we explained before, just for that instant, increases its Flame. If this glowing Coal now had been so laid on the flaming Alcohol, that one part of it had been above the Surface of it contiguous to the Air, then it would have continued burning with the Alcohol, and that pretty fiercely.

EXPERIMENT III.

An examination of the purest Flame.

I took a good deal of pains formerly to find out some Experiment that should be sufficiently evident to the senses, by which I might come at the knowledge of

of the action that Fire exerts upon its *Pabulum*; and at last, I brought the affair to the issue that I am now going to explain to you. To this purpose then, I again set fire to this pure Alcohol contained in this clean cylindrical Brass Vessel; and thus burning, as you see, I place it upon this Table, and put over it this large glass Cucurbit, which is one of the biggest that the Glass-makers can blow for chemical uses, and whose bottom I have carefully cut out in a circular figure, so that it is now a true Bell, whose diameter at bottom is ten inches, and whose top has an orifice that will admit one's little Finger. This clear glass Bell then thus every way surrounding the burning Alcohol, you'll evidently perceive all the *Phænomena* that I related to you, and shew'd you under the former Experiment. Fig. 3.

The first thing, then, remarkable here is this, that the whole surface of the Bell appears, as you see, opaque, from the action of the Flame burning within, so long as the Bell itself remains cold: But now, as it grows warm by the Fire that's under it, you perceive that it begins again to look clear. By the same action continued, it is at present actually hot; and it is now become perfectly pellucid. If you look ever so attentively, now, you will not perceive the least kind of Fume in the whole cavity of the bell, but the Air throughout the whole space appears perfectly clear. And as the vessel in which the Alcohol is contained is cylindrical, hence the Flame, as far as the eye can discern, continues exceedingly equable, from the beginning to the end. At the bottom, however, of the inside of the Bell, you perceive something running down in streaks, like those that are formed in the distillation of Spirits.

This yields
an exceeding
limpid thin
Vapour.

This liquor now is by no means the true spirit of the Alcohol, for it has a perfect watery taste. But that you may perceive this evidently yourselves, observe the fine Vapour that exhales through the upper Orifice: This, if it was really the Alcohol, raised by the Heat, would immediately take fire upon the application of this lighted match, as we saw in the preceding Experiment; but, on the contrary, when I move it into this exhalation, you observe the Flame of the Sulphur is extinguished by the Vapour, exactly as if it was held in the steam of hot Water. But again, I'll put this burning Match under the Bell, and thus hold it in the very place where the Alcohol is burning, and diffusing its Vapour; and you see, now, that it remains a'light, and burning, till it is quite consumed, but not in the least sets fire to the fumes that rise from the flaming Alcohol, and fill the whole Bell; which, had they retained their former nature of Alcohol, after they had passed through the Flame, must necessarily have taken fire upon the application of the burning Match. Hence, therefore, it seems to appear, that this matter, which, of all that we know of, is the most inflammable, whilst it is thus converted into Flame, and by this means, likewise feeds the Fire, is really changed into another substance, which, after this alteration, is no ways capable of supporting it any longer, but as far as we are able to judge, acquires the nature of Water. Did, then, this Water actually reside originally in the Alcohol, and so as not to be separated from it by any other method than this? Or did the Fire, by burning the Alcohol, convert it into Water, by a true transmutation? Or, lastly, was not this Water, in reality, supplied by the Air, during the time that the Alcohol was burning? These things, farther Experiments, made.

And indeed
an aqueous
one.

made by men of judgment, may hereafter determine. But here give me leave to caution you, that it's necessary, that the Alcohol used for this purpose should, by a gentle distillation, in a tall vessel, be drawn off of the driest Alcaline, fixed Salt of Tartar, that, by that means, the true Spirit of Wine may be freed from all the Water that it is possible, by any Art, to separate from it; and with this sort it is, that I make these Experiments before you, very well knowing, how closely the Water coheres with the pure Spirits, even with such an union, that is not easy to be dissolved. After I had examin'd Alcohol in this manner, I found, that the famous *Geofry*, the younger, a Gentleman of great application, and a particular genius for these Inquiries, had, in the *Mem. de l'Ac. roy.* Ann. 1718, published some very accurate and ingenious Observations, which, though made with another view, yet elegantly confirmed what I had before discovered by the method I have just mention'd. For my part, I was vastly solicitous to know what physical alteration it really is that inflammable matter undergoes, when it is so exposed to fire, as to produce Flame, which is the purest of all Fires; and what at the same time, happens to fire, whilst this combustible matter, in conjunction with it, rises into Flame: For I imagined, if I could once come to a certain knowledge of this, it would be a good step towards getting a better insight into the nature of Fire itself. For this purpose, therefore, I prepared a matter, which being burned in a cylindrical vessel, and thus being forced to pass through the Flame, that intirely covers the whole surface, would totally feed the Flame, and be itself totally converted into Flame, without Smoke, Soot, or *Fæces*. When this, then, was exposed to the pure Air alone, (without the admission of which all Flame goes out) and so set on fire, I found it was intirely consumed into Flame, that this Flame produced a very fine Vapour, and that this Vapour might be condensed into Water, or, at least, wou'd generate it: And thus far I was then able to proceed, and no farther. But had I now as much leisure as I have inclination for these inquiries, I wou'd endeavour, by the help of more of these glass Bells, to collect some quantity of the Water thus produced; for I observed, as you yourselves likewise did just now, that far the greatest part of the Vapour passed through the upper Orifice, and was by this means dissipated. Over this Bell, therefore, there should be hung another of the same kind, that this Vapour, likewise, might be there received, condensed, and rendered fit for examination. And a third, again, might be suspended over this, so that by this means at last the Vapour might be totally collected. The properest time, now, for making this inquiry is, when the weather is exceeding cold, that the Vapour may be very quickly condensed by the Cold, and frozen in the upper Glasses. And these Experiments should be likewise made in a place that is very dry, and not incommoded with wind: Nor do I at all doubt, but that the thing will some time or other be discovered, the knowledge of which is as valuable as any thing in natural Philosophy, and will be of infinite service in the chemical Art. I know, indeed, that the worthy *Geofry* has inferred from his Experiment, that he could procure from pure Alcohol, by converting it into Flame, more than half its quantity of Water; and it is certain, that he did exhibit so much. But this excellent Chemist is well apprized what a great quantity of Water is diffused about through the Air; how imperceptibly this Water quits the Air, and insinuates itself into saline, dry, spirituous

spirituous Bodies, and, by subtilly mixing itself with them, often overturns our Observations: The blue Flame of the dryest burning Sulphur exhales into the Air, to a great compass, and, if it is collected under a Bell, produces a very sharp, acid Liquor; which, if the weather is dry, is in a small quantity, and always so much the stronger; but if the Air is moist and cloudy, it is in a greater, but then it is more watery. From this we can, by a gentle Fire, separate a large quantity of insipid Water, and from the remainder prepare a small portion of a thicker liquid, that is exceedingly acid: If you expose this last now to the Air, in a broad vessel, when thus simple, and freed from its Water, the Water in the Air will immediately unite itself with the pure Acid, increase both its weight and its bulk, and at the same time dilute, weaken, and render it less efficacious. Perhaps, now, the very same thing may happen to the Spirits, whilst they are burning. These things, however, bring again to my mind the expressions of the ancient Alchemists, who called them, the moving, or governing Spirit, the Child of the Sun, the Offspring of Fire, and the internal Fire of Bodies.

And another part that does not fall under the cognizance of our senses.

Is it not possible, then, that this pure Spirit, which, in conjunction with Fire, produces Flame, and is absolutely, and totally inflammable, may be but an exceeding small part of the Body in which it is contained, but dispersed thro' a large quantity of Water, and intimately united with it? Certainly, though we endeavour ever so artfully to confine this principal, we always find it so infinitely subtil as to escape our nicest Observations. Tired in these inquiries, I confess, for my own part, that I have for a long time past desired nothing more earnestly, than rightly to understand the proper nature of that Matter in the Alcohol, which is truly inflammable; for I knew that I here was in possession of something which is perfectly inflammable. And I have for a good while been satisfied by Experiments, that all other inflammable Bodies are only so, as they contain Alcohol in them, or at least something, that on account of its fineness, is exceedingly like it, the grosser parts of them that are left behind, after the separation of this subtil one, being no longer combustible. I had the pleasure, therefore, of believing, that if I could but once discover this in Alcohol, I then could very easily comprehend how Fire is supported in all other combustible Bodies. But how was I disappointed when I found that Alcohol, by passing through Flame, would burn away into a Vapour, in which I could not discover any Alcohol; so that if this was really the remains of the Alcohol, it left nothing behind it but an exceeding pure Water. These therefore I acknowledge the boundaries of my knowledge upon this subject: The *Pabulum* of Fire, when consumed by Fire, leaves a Water behind it, but becomes itself so vastly fine, that it is dissipated into the Chaos of the Atmosphere, and gets beyond the reach of our senses.

EXPERIMENT IV.

But by this new Experiment, the Opinion which I just now laid down, will appear more evident. For this purpose I have provided a live Coal, in this earthen Pan, which is so perfectly red quite through, that, as you see, there is not the least appearance of Smoke; the Pan too is perfectly clean, and very dry. Upon the Coal I place this pure brass porringer, which is about an inch deep, round at bottom, and four inches in diameter. Into this I now

A instantaneous production of the purest Flame.

pour

pour some choice Alcohol of Wine, to the height of half an inch ; and then cover the whole, as before, with the glass Bell. You may perceive, now, that the Alcohol, by means of the Coal in the Pan underneath it, boils pretty strongly in the brass vessel, but does not take fire, or diffuse any Fume that is visible within the cavity of the Bell ; nay though the exhaling surface of the boiling Alcohol is so broad, yet there does not appear the least Vapour coming out of the upper Orifice. In the mean time, however, you begin to perceive some streaks of the Spirits running down the sides of the Bell, especially about the lower parts of it. As you see, now, a considerable part of the Alcohol is, by boiling, exhaled out of the brass porringer, it's time for us to try what will be the effect of applying a lighted Match to the upper Orifice of the Bell. This then I'll do ; and you observe, that whilst I thus hold it over the mouth, the Flame of the Match does not set fire to the Alcohol, that is floating about within the Bell, but is rather itself extinguished. Hence, therefore, as the Alcohol, that is now dispersed in the Bell, does not, by this means, take fire, you will be apt to imagine, that it does not appear, by the former Experiment, that the Alcohol, which was burnt by passing through the Flame, did really lose its inflammability, or else, that this has lost it likewise, purely by exhaling without burning at all : But please to attend, with a little patience, and you will soon be of another opinion. Observe then this lighted Match, which I now hold in a pair of Tongs, that I may be at a convenient distance from the effect of this dangerous Experiment. In this manner, then, I cautiously carry it along above the Table, in a horizontal direction, towards the glass Bell, 'till the Flame of it comes underneath the lower rim of it ; and you see as soon as ever the Flame reaches within its cavity, the whole space within the Bell, that is now filled with the Vapour of the boiling Alcohol, like Lightning, instantly flashes out, and that with a great noise, and such a violence, that the moment it takes fire the Flame rushes out at the bottom, between the Bell and the Table. This happens, now, because the whole cavity, being filled with the very minute particles of the Alcohol, and at once set on fire, is not able to contain all the Flame, which, therefore, will diffuse itself through those parts where there is least resistance, *viz.* in this case at the bottom ; at which place, could it not have found a vent, it would have either blown off the Bell, or burst it in pieces, not without a great deal of danger to the persons about it. If ever, therefore, you make this Experiment, take this caution, never to come too near the Bell when you apply the lighted Match, nor ever to hold the Match in your hand, without a pair of Tongs ; for otherwise, that Flame which bursts out at the bottom may very easily burn your hands and face. This, then, may suffice for the first part of this Experiment ; let us now turn to the other.

Which sets
on fire boil-
ing Alcohol.

The very moment, then, that the Flame was excited in the Bell, you observed the whole surface of the Alcohol that was boiling in the brass Porringer to be likewise perfectly covered with a bright Flame ; which you saw did not in the least take fire before, tho' the Fire underneath it made it boil pretty strongly. Hence, therefore, it is very evident, that Alcohol will not easily be set on fire without the application of Flame to it. But the Flame of the Alcohol, now it is once lighted, continues burning under the Bell, till the Alcohol is quite consumed, nor goes out before the Dish is become perfectly

dry.

dry. In this beautiful Experiment, now, nothing formerly gave me more pleasure, than what you have all seen at this time, viz. that

The Flame that was raised by the match, at some distance from the vessel in which the Alcohol was boiling, diffusing itself through the whole cavity of the Bell, set on fire the Alcohol that was contained in that vessel: But the very moment that this began to flame and burn, the Flame in all the other parts of the Bell instantly disappeared, and this only upon the surface of the burning Alcohol remained quite to the end, till all the matter of the Alcohol was perfectly burned away; nor was there, from the first moment of accension, during the whole time, any other flame excited throughout the whole capacity of the Bell, than what just hovered over the Alcohol in the Porringer. Does it not, therefore, evidently appear, that pure Alcohol, though it is agitated with a pretty strong Fire, provided it is not lighted, may be diffused through large spaces, without undergoing any alteration, and that it will still possess its inflammability in the same degree that it did before, so that if you apply a Flame to it, it will in a moment take fire, and burn with a great deal of violence? Nor is it hence less certain, that the very same Alcohol, when it is forced to pass out of its vessel through the Flame that covers its substance, and is by this means forced to feed the Flame itself; I say, when it has thus exhaled through the Flame, into the cavity of the Bell, it is not less certain, that it has so perfectly lost its aptitude to Flame, in an instant, that though the parts of the Alcohol are now attenuated by so much stronger a Fire, yet they can never afterwards be set on fire by the Flame that continues burning under the Bell. This extraordinary and surprizing *Phænomenon*, now, deserves, certainly, the maturest consideration; for it does not at all seem probable, that the Fire can perfectly expell all the Alcohol, out of the large space of the Bell, the very moment it has burnt it: And yet if the particles of the Alcohol, when they have passed through the Flame, float about in the cavity of the Bell, which seems very likely, then, if they remained still inflammable, they must necessarily be set on fire by that very Flame. What shall we say, then, Gentlemen, in this case? If the only pure inflammable matter that we know of in nature, when it once takes fire, totally loses its inflammability, must not there, of consequence, so much of the true *Pabulum* of Fire be every day destroyed, as is thus consumed by Flame? And for this reason, therefore, must not this at last be quite spent, if it could not, by some means or other, be recruited? Is this, therefore, continually supply'd by the operations of nature, in the bowels of the earth? And by which of them? By those, certainly, by which it generates Oil and Spirits. And, hence, in particular, by vegetation, fermentation, putrefaction, and distillation. But all these operations, whether artificial, or natural, are performed by the efficacy of Fire alone. Fire, therefore, which destroys combustible matter, is that cause in the universe, by whose energy it is again renewed. Or does the other opinion seem more agreeable, which we proposed before, when we made this Query, whether the matter that is intirely inflammable, does not, in reality, consist of a large quantity of Water, intimately united with a small portion of some other principle, that is vastly subtil, and very much resembles, nay is, perhaps, Fire itself? Whence this Fire being separated from the Water, by the

And is, at the same instant, extinguished itself.

action of burning, would again be freed from its confinement, and become true elementary Fire. If you suppose this to be the case, then ultimate, inflammable matter would be Fire itself; and, hence, when it is set at liberty from every other Body, would, of consequence, be dissipated into the Air.

EXPERIMENT V.

The extinction of
Flame by
Oil.

I dip this flaming Match into this pure, cold, distill'd Oil of Turpentine, and you see it is put out in the same manner as if it was immersed in cold Water, exactly as it happened before in the Alcohol. And again; I throw this live Coal into the same Oil of Turpentine, and by this means it is perfectly extinguished, without producing the least appearance of Flame. Hence, therefore, almost all those things that we before asserted of Alcohol, will hold true likewise of this Oil; and for this reason, as they may be consulted there upon occasion, it is needless to repeat them here.

EXPERIMENT VI.

The increase of
Flame by
the same.

I have again put some of the same pure distill'd Oil of Turpentine into this brass cylindrical Vessel, and set it upon the Fire 'till you see it begins to boil: To the Vapour now that exhales from this boiling Oil, I'll apply this lighted Match; and you perceive that when I do this, it is much longer before it takes fire than the boiling Alcohol was, tho' at last it does light and burn. You observe farther, that a black Smoke arises gradually from it, and as this appears, the Oil burns with more violence, till at last you see the Flame grows very fierce and vehement: And now it is burnt out, there are no *Fæces* left at the bottom, but it is all intirely consumed. The purer now, and more limpid this Oil is, so much the less black Smoke it always emits, and burns away more quietly. This therefore is the case, when it has been purify'd by repeated Distillation, for in every Operation it gets rid of some of its *Fæces*, but at the same time approaches so much the nearer to Alcohol, in lightness, limpidity, purity, and disposition to burn. But tho' by this means it constantly comes nearer to the nature of Alcohol, yet still it does not in reality ever become Alcohol, as it is never capable of being mixed with Water.

EXPERIMENT VII.

Examination of the
Flame of
burning Oil.

The same Oil of Turpentine being exposed to the Fire in this brass Vessel till it boils, and being then set on fire, I'll place it now, whilst it is burning, upon this earthen Plate, and cover it with the glass Bell. It burns now you see as in the sixth Experiment, but then with this difference, that it sends forth a black, thick Smoke, that fills the whole cavity of the Bell, rises through its upper orifice, fullies its sides with Soot, and fixes at the same time a kind of watery Vapour all round it: So that one would believe, that Water was here likewise produced from the burning Oil, or else by the concurrence of the Air. Hence, therefore, it appears, that Oils, which come nearest to Alcohol, tho' they are acted upon by Flame, and compelled to pass through it, yet will still retain some inflammable parts, that are not perfectly burnt away, but are only converted into a Coal; and that these being expell'd by the Fire out of the Flame in form of a sooty Smoke, are dissipated to a great distance, and afterwards being deprived of their first motion fix to the sides of Chimnies.

And

And this the fetid smell of burning Oil, which may be perceived a great way off, sufficiently demonstrates. These parts therefore, seem of too thick and tenacious a nature to be so soon reduced by the quick action of the Flame, to the subtlety of the finest Alcohol. When these Oils now are made use of for common Lamps, and have a Wick in them that is every way surrounded by the Air, they then burn with a smaller flame, and much more leisurely; and at the same time they produce a great deal more Soot, as the Blackness that soon settles upon a clean Paper held over them plainly evinces. But when they are thus set on fire in a cylindrical Vessel, the whole Surface of the burning Oil being perfectly covered with the incumbent Flame, all the Particles of the Oil as they consume, must necessarily pass through the Flame itself, and consequently will be more forcibly attenuated, and changed by the action of the Fire, than they are in the Lamps abovementioned; for there the oily Particles being put in agitation, have a free passage into the ambient Air, from every point of the Surface of the Flame, and hence fly off, without being totally altered by the force of its Fire. From all that has been observed then, it seems exceeding probable, that if by any Art Oils could but be reduced to the subtlety of Alcohol, then the Flame that is excited by them, would be free from Smoke, and the Fire from Soot.

EXPERIMENT VIII.

I have in this clean brass cylindrical Vessel, mixed some very pure Water, with an equal quantity of the choicest Alcohol, so that now after shaking them together, they appear you see a homogeneous Liquor. This Mixture then being heated, and set on fire, I'll place again under the glass Bell. You observe now, that the Flame that rises hence, is much weaker than that which we saw in the first Experiment upon this Subject; nor does the colour of the Flame by any means come up in brightness to that of the pure Alcohol. And you perceive too likewise, that this Flame, before it goes out, hovers a long while over the Surface of the Liquor, and then disappears, leaving the Water behind it in the bottom of the Vessel, in which there remains but a very small portion of the Alcohol, as the taste of it evidently demonstrates. Hence then we understand, that tho' Alcohol is mix'd with Water, yet it will be extracted thence by the power of Fire, and consumed by it; and that at the same time the Water is repell'd both by the Alcohol, and the Fire.

Examination of Alcohol and Water burning together.

EXPERIMENT IX.

In this very pure Alcohol, I have dissolved some fine Camphire. This Mixture now, I'll set on fire, and place burning under the Bell, as in the former Experiments: And the event is pretty remarkable. For first you see it takes fire exactly in the same manner as if it was simple Alcohol, and all the *Phænomena* appear perfectly the same; and that the pure Alcohol is thus first consumed, and the Camphire without burning is depress'd to the bottom of the Vessel, where it is collected in a Body by itself. But the Alcohol now being all dissipated by the Fire, you observe another Flame arising perfectly different from what appeared before, whilst the Alcohol was burning; for this you see is stronger, whiter, more lucid, and its Vibrations are greater than the former. At the same time too, this Flame produces a black Smoke; and then

Of Alcohol and Camphire.

both the smell and taste of the Camphire ascend from the Flame, and disperse themselves not only through the cavity of the Bell, but also through this whole apartment. This Flame now you perceive lasts as long as there is any Camphire remaining, and when it goes out, leaves no *Fæces* behind it in the bottom of the Vessel. Hence, therefore, we may learn, that if inflammable substances of different natures are united together in one compound, they will not burn away at the same time; but the most subtil part will be first of all consumed by the Fire; and the remaining grosser part will continue defended as it were under the burning Flame, and will then only begin to take fire when the former is dissipated. In combustible Substances, is that always first, and most easily set on fire, that is the lightest of them all? This certainly seems to be the case universally. Is the Flame that is excited in burning Alcohol too weak to set Oil on fire? This too seems exceeding probable: And hence, as soon as ever the Oil, or the Camphire dissolved by the Fire begins to burn, the Flame immediately you see becomes fiercer. Does then Fire by burning combustible Bodies, as well as by distilling them, separate their differently inflammable Principles, according to their various degrees of subtlety, or spissitude, the Spirits, for instance, first, then a thin Oil, next an Oil that is a little thicker, and lastly, a thick, pitchy, tenacious Oil? This plainly appears in this Experiment. Is this then the reason, that Charcoal, and the like Substances prepared by Fire, and consisting of an Earth and Salt covered over with this last very thick Oil, yield a stronger Fire than can ever be procured from Wood before it is thus burnt? This certainly is found to be universally true, that the Fire that is excited by burning Oil, is always so much the more violent, as the Oil has a greater spissitude, and is more ponderous. That this was the case just now in burning Alcohol, and Camphire, you yourselves are witnesses. And all these things are confirmed by the most common Experiments: As every body knows, that a Fire then gives most Heat when the ultimate combustible matter comes to be burnt. The burning therefore of combustible Bodies must not be looked upon as an action, that at once mixes, blends, and consumes all the different kind of inflammable Elements together; for it appears on the contrary, that this is effected distinctly, and successively.

EXPERIMENT X.

Of Oil and
Alcohol.

Let us now make the same trial upon Alcohol of Wine, so intimately mixed with fine distill'd Oil of Turpentine, that the Mixture appears perfectly homogeneous. This therefore I'll set on fire under the Bell in the same cylindrical Vessel, that we may see what will be the event. In the first place then, we observe rising from this burning Mixture, a beautiful, strong, very bright Flame, which is exceedingly equable, and appears divided at top into two parts. This now, as far as we can discern, does not exhibit the least appearance of Smoke, or generate or deposit any visible Soot; but yet it has so discoloured this white Paper that I held over the upper Aperture of the Bell, that you perceive it is grown quite black; whence it evidently appears, that there immediately upon the mixture arises something in this pure simple Liquor, which is able to disengage itself from the Flame, before it is perfectly consumed. At the same time, however, there is not the least disagreeable

agreeable smell in the Vapours of this Flame; and it wastes away so quietly, that there is not the least noise produced by it whilst it is burning. But in the second place, the Flame having now consumed all the Alcohol that was contained in this Mixture, the appearance you see is intirely altered: for the Oil of Turpentine is now left burning at the bottom of this Vessel, and the Flame of it leaps, sparkles, and makes a noise, sends up a great deal of Smoke, and leaves at the same time some resinous *Fæces*, which are not combustible by this Fire.

EXPERIMENT XI.

I have again mixed some perfectly pure Alcohol, and a very strong alkaline Spirit of *Sal Ammoniac* in equal quantities, and by this means have procured this surprizing *Coagulum*, which was long ago known to *Lully*, and was so much celebrated by *Van-Helmont*. And I think it worth while to expose to your view what I have myself observed in burning this in the same manner as we did the former. What now do you judge will be the consequence? The unforeseen events that so often deceive our expectation in trials of this nature, make you cautious no doubt how you determine. Let us therefore make the Experiment. You'll now answer then, that the Alcohol will be first set on fire; that this being consumed, and dissipated, the Flame goes out; and that then there remains at the bottom the alkaline Spirit of the *Sal-Ammoniac*, almost intire. And this is certainly the case; for you observed, that when this pure *Offa-Helmontiana*, was heated, set on fire, and placed under the Bell, it first of all exhibited a very weak, equable Flame, scarcely visible, without Smoke, or Soot; tho' the inferiour part of the Bell however, was render'd pretty opake by the exhaling Vapour. You then took notice in the second place, that the Flame grew stronger, more lucid, sparkled, made a hissing noise, grew unequal, and hover'd about, and soon after went out. At last there was diffused a smell of a volatile, alkaline, spirituous Salt; tho' the Vapour collected into a Liquor on the sides of the Bell was almost insipid; and as I shew'd you, there remained at the bottom an exceeding sharp, strong, Spirit of Urine, very volatile, and strong scented. In this Experiment now there's one very singular *Phænomenon* that well deserves our observation, which you'll conceive in the following manner. The Salt contained in the alkaline Spirit of the *Sal-Ammoniac*, is much more volatile than even the Alcohol itself; as appears in the sublimation of this *Offa* of *Van-Helmont*, with a very gentle Heat; for in that Operation, a dry Salt always rises first; and yet whilst it is burnt in this manner, the Alcohol in this Mixture is first of all attracted upwards into the Flame, and so consumed; and altho' this Mixture is heated in the brass Vessel, and is at top very forcibly agitated by the Fire, nevertheless, this very volatile Salt is forced downwards with its Water, and is so confined under the incumbent Flame, that it is not capable of disengaging itself, or breaking through it. And this, Gentlemen, I beg you will consider in a particular manner, as it will help us to a knowledge of the nature of Flame, and combustible matter, which has not hitherto been much taken notice of. But since now Camphire is looked upon by many famous Chemists, as a solid *Sal volatile Oleosum*, concreted like *Van-Helmont's Offa*, from two principles, the one a saline, the other an oily one; it will be worth while to try what will be the consequence of burning.

Of the *Offa*
of *Helmont*.

burning this under the Bell likewise. We find, then, that upon the application of a Flame to it, it very readily takes fire; and then flames in such a particular manner, that one cannot look upon it without admiration. This Flame, as you see, is white, equable, and long; and terminates in a smokey cone, which is of a great length, and very small. But what a copious, dense, black Smoke does it likewise disperse through all the Bell! and at the same time, as you perceive, there are abundance of little black footy particles, thrown out on all sides by the Flame, which are so heavy, that they fall to the bottom, and in which there remains the smell and taste of the Camphire, though the colour of them is black. In the bottom, now, there are left hardly any *Fæces*, the Camphire having quite done burning. Hence then we may make some judgment of this wonderful Body; and you'll believe with me, that it is a very perfect simple Refin, or an Oil existing in a solid form.

EXPERIMENT XII.

Of Alcohol
and Earth.

I have here a very pure Earth, *viz.* *English Chalk*, reduced to powder; with which I'll mix some of the same Alcohol of Wine, as intimately as possible, and set it on fire under the Bell, as in the former Experiment. The Alcohol, then, you perceive, burns away intirely, as in the third Experiment; but the Earth, you see, remains at the bottom, perfectly dry, pure, intire, and without any Alteration.

EXPERIMENT XIII.

Of Alcohol,
Oil, Cam-
phire, the
Offa Helmon-
tiana, and
Earth, all
mixed toge-
ther.

But none of these Experiments are more entertaining than that which I am going now to shew you. For this purpose I mixed Alcohol, Camphire, and Oil of Turpentine together, in such a manner, that they were most accurately dissolved one amongst another; and to these I then added the *Offa* of *Van Helmont*, which will bear conveniently enough too, to be united with the former; and I afterwards worked all these, thus mixed together, with some of that fine earth, *English Chalk*, so as to form them into a mass, with which I then mixed some shavings of wood. This, now, I'll set on fire before you, under the same circumstance as in the former Experiments, and beg that you will observe the issue. The Alcohol then you see burns away, in the first place, almost in the same manner as if it had been set on fire by itself. This being consumed, the Oil of Turpentine next takes fire, and sufficiently distinguishes itself by its particular *Phænomena*. In the third place, you see the evident signs of the burning Camphire. And, at last, the alkaline spirit of the Sal-Ammoniac, the shavings of the wood, and the pure Earth, are left at the bottom. You observed here how strong, unequal, and red, the Flame was, and how it crackled and made a noise, whilst it was burning: And what a small quantity of Smoke rose in the beginning; which afterwards increased, by degrees, till it at last became exceeding black, and very thick. Then too there was produced a very black and dense Soot. And towards the end you perceived flakes of Soot flying about within the cavity of the Bell. As for the Wood, you see the Flame has not affected it. From all these things, then, carefully considered, you have, I think, a fair opportunity of discovering the method which nature makes use of in consuming combustible matter by Fire; which certainly is very different from what people generally imagine;

imagine; at the same too you have learned, that there is hardly any thing in all natural philosophy that is more difficult to understand, than what corporeal substance that really is, which is solely inflammable, in combustible Bodies. It is a very easy matter, indeed, to talk of Oils, Sulphurs, and nitrous substances too, which some people have very injudiciously added, and to assert, that these are the bodies that constitute inflammable matter: But to disengage that which is purely inflammable from every thing else, and thus to examine it, and discover its nature, is a very difficult task; nor could I ever meet with any one who could give any tolerable account of it; much less of the alteration that Fire actually induces in it whilst it consumes it. But of this enough.

SCHOLIUM I.

1 In the first place, then, there is discovered in nature, and that produced from Vegetables, by fermentation and distillation, a certain Liquor, of all that we are hitherto acquainted with, the simplest, the most limpid, the lightest, exceedingly immutable, and capable of being mixed with Water and Oils, which is of such a nature, that if it is heated, and has a Flame applied to it, it will easily take Fire, will then totally burn, and feed and support a pure Flame in every point of its surface that is contiguous with the Air, and by this means will have its whole substance gradually consumed into Flame, as its particles, by degrees, come to be contained in this surface: And this will succeed in such a manner, that so long as there is the least drop of this liquid remaining, the Flame will continue to burn, and the very moment it is intirely burnt away, will totally disappear, without leaving the least indication of Flame behind it. We are therefore in reality masters of such a Fluid that properly deserves the name of Aliment or *Pabulum* of Fire; since as far as our senses are capable of discerning, it may, by burning with an open pure Flame, be totally and absolutely converted into the purest Fire. For if you please, Gentlemen, to consider this affair attentively, what does become of all this Alcohol, when it is thus consumed? Is it not changed into the purest Flame? But is not all the Flame that is excited and sustained by this means, exactly the same in every effect as that Fire which we have already described by its proper physical characters? Certainly there is not any one thing taken notice of in our whole history of true Fire, that does not equally hold good of the Flame that is fed by this Alcohol.

Alcohol the
one pure in-
flammable
Body.

2. But we observe here in the second place, that the Fire thus collected about the Alcohol, persisted to be Fire there, so long as any of the Alcohol remained, without adding any other Fire to it, or bringing any to it by any means whatever; so that when once the Alcohol was set on fire, it was constantly present there, nor needed any other Body, or any other *Pabulum* to continue it, when it was thus excited in the open Air.

Which,
without any
assistance,
supports
Flame, when
once excited.

3. Thirdly, there is this farther remarkable, that as soon as ever the Alcohol was consumed, there was not the least remains left of the Fire or Flame; so that it did not continue one moment after that was burnt away.

Which goes
out as soon
as this is con-
sumed.

This *Pabulum*, therefore, is the true cause that procured at least the presence of

of

of all that Fire, in that particular place; for this never remains when that is dissipated.

Nor does it
produce any
Smoke.

4. Fourthly, there is this particularly singular in this Aliment of Fire, and the Flame produced by it, that from the first moment it began to burn, to the moment of its extinction, it never emitted the least Smoke, which every other kind of fuel is observed to do, either at the beginning or the end.

But a Water.

We found, indeed, that a moist Vapour did evaporate from the Flame of the Alcohol; but this being a very limpid aqueous fluid, formed only a perfectly pellucid exhalation, which being afterwards collected, produced a pure simple Water, in which there was not discoverable, the least colour, thickness, or oiliness. This, now, is particularly surprizing, as we don't know of any other liquid, or solid Body, in the whole compass of nature, that will feed and sustain fire, absolutely without any Smoke at all.

Nor yields
any Ashes.

5. We learn again from these Experiments, in the fifth place, that Alcohol does not contain any matter that is fixed and incombustible; for if it is perfectly pure, as it must always be for this Experiment, when it goes out, it won't leave the least spot behind it; nay, it will be totally converted into more Flame, without producing the very smallest quantity of *Fæces*. This again we observe no where else but in Alcohol; for all other inflammable substances leave some *Fæces* behind them, which are not combustible; though indeed, those that are very pure leave but few. *Naptha*, *Petroleum*, and *Camphire*, yield a bright, strong Flame, but they deposite something in the bottom of the vessel where they are burnt, that is not so combustible: Alcohol is the only one that leaves nothing.

Nor causes
any disagree-
able Smell.

6. Sixthly, Alcohol, when it was thus set on fire, did not diffuse any disagreeable Smell, of a different nature from what naturally belongs to it. But this again is not the case with any other combustible matter; for every thing else sends forth a rancid, footy Smell, or an empyreumatical one, when it is reduced to Flames in the Fire. One would thence, perhaps, be ready to imagine, that all the parts of Alcohol are perfectly homogeneous in their natural state, and that they remain so during their burning, and after they are burnt; unless those observations, of Water's rising from the Flame of Alcohol were against it, and taught us, that even in Alcohol there resides something that is not combustible.

It has no so-
lid Substance
formed from
it.

7. In the seventh place, we hence learn farther, that in this Body which alone when exposed to Fire, discovers the properties above mentioned, there is not the least appearance of any solid substance; not even to the sharpest eyes, assisted by the most perfect Microscopes: Hence, therefore, a solid form is no ways necessary to render Bodies a proper *Pabulum* for Fire; but on the contrary, the most liquid one that human observation has ever yet discovered.

But is tena-
cious of Wa-
ter.

8. But we perceive yet again, in the eighth place, that this Alcohol is of such a nature, as to attract, take in, and unite to itself the purest, elementary Water; but that at the same time the Flame excited in the Alcohol, will again attract the pure simple Spirits of Alcohol out of the Water and Alcohol thus blended together, and having drawn them to the surface of the mixture, will then imbibe them, consume them, turn them into Flame, and by that means separate all the pure Alcohol from the Water that is mixed with it; and at the same time refusing to be united with the Water, will repel this, and deposite it in the bottom of the vessel.

9. It's

9. It's surprizing now, in the ninth place, that the very same Alcohol, perfectly the same in every respect, may, by fermentation, and a gentle distillation, be procured from every kind of known Vegetable, that is naturally disposed to ferment: Whereas, excluding the vegetable Kingdom, and the assistance of fermentation, examine all the Bodies you are acquainted with in the universe, and you will not find one that is possessed of the properties above described.

And is a true Offspring of Vegetables.

10. But farther, in the tenth place, from what has been observed in these Experiments, we are of opinion, that though Alcohol be ever so pure, yet there is in reality some difference in its constituent parts, though not discoverable by any other Art than setting the Alcohol on fire; for by this means it is separated into a Water, which when alone extinguishes Fire, and into an inflammable part, which is truly consumed in the Flame, and reduced to such a subtlety, that it afterwards becomes quite invisible. *Van Helmet*, indeed, has told us, that by the application of Salt of Tartar to the purest Spirit of Wine, he could instantly convert it half into Water, the other part being retained and held fast by the Alkali; but I always doubted, whether he should not be understood to speak there only of rectified Spirit of Wine, of which it is strictly true, and not of pure Alcohol, skilfully prepared, of which I believe no body has hitherto ever made it appear. If these things, now, are really true, as they certainly seem to be, then Alcohol would very much resemble Sulphur, as both of them would be totally consumed in the Fire; both of them would yield a blue Flame; be resolved into one invisible part, that is inflammable; and whilst they are burning, yield another part that extinguishes Flame; which in Alcohol is a mere inactive Water; in Sulphur, an exceeding acid Salt of Vitriol diluted with a portion of Water, whose Vapour is hence perfectly suffocating.

But compounded.

Other substances changed in the Fire like Alcohol.

11. In the eleventh and last place, we hence farther infer, that solid compound Vegetables, whilst they are burnt, are changed and agitated in the same manner; inasmuch as their inflammable part alone is consumed by the Fire, the rest being dispersed into a matter, which if it is again collected, becomes visible, nay and sometimes combustible too; or else, being converted into a fixed one, which we then call Ashes, or *Fæces*.

SCHOLIUM II.

1. In the first place, then, Alcohol seems to have something of the nature of Fire. This appears evident from many of its effects. Both of them coagulate Blood, *Serum* of Blood, and bile, and parch up, as it were, the flesh, nerves, and *viscera* of Animals, whites of Eggs, and Bread. Is Alcohol, then, a magnet to Fire? It is certain, it has a power of attracting the light that approaches it. Does the mixing Alcohol and Fire together cause an effervescence, and by this effervescence produce Flame?

Alcohol agrees with Fire.

2. Secondly, all other inflammable Liquids, let them be ever so subtil, if they are burnt in the manner proposed, yield a visible black Smoke and Soot, and leave some *Fæces* behind them, which are not perfectly combustible. This incombustible matter in the purest Oil is at first a mere Earth, to which there still adheres some portion of Oil, in which respect, as it retains the nature of a Coal, there is yet something inflammable remaining in it. But when these Oils are often depurated by an artful distillation, they always depofite an Earth,

Other Pabula produce *Fæces*.

D d

grow

grow constantly thinner, become more inflammable, produce less Smoke, Soot, and Ashes; and thus continually come nearer to the nature of Alcohol: Repeat this operation, in the mean time, ever so often, yet you'll never reduce them to such a subtlety that they'll bear being diluted with Water.

What would
be the effect
of Alcohol
upon Fire if
it had no
Water mixed
with it?

3. Thirdly, that Body, that we have discovered to be absolutely inflammable, so that it will totally feed and support Flame, yields not the least Smoke in this Fire, produces no Soot, nor leaves any *Fæces* behind, but as far as our senses are able to penetrate, has its whole substance converted into Fire; or at least when it is set on fire affords us nothing but a pure Water. If it were possible then by any Art to separate that part of the Alcohol, which is perfectly combustible, and hitherto unknown, from the Water that appears to be collected during its burning, and this afterwards should be applied singly to pure Fire or Flame, what would be the consequence? Would it then burn successively, as it does now it has a mixture of Water with it? Or would it like lightning be consumed in a moment? A close meditation, certainly, suggests a good many things upon this head; but this pure speculative knowledge, must not be too much indulged, but must give place to that more solid one founded upon Experiments.

The true
Pabulum of
Fire vanishes
in it intirely.

4. From what has been demonstrated, we may venture to assert, in the fourth place, that that part of inflammable Vegetables, Alcohol, or Oils, which in reality is not combustible, is either an intimately united Water, a Salt, or an Earth. These, then, if they could be perfectly separated from Oil, or Alcohol, the remainder would be that simple pure matter, which is totally convertible into the purest Flame, without *Fæces*, Smoke, or Soot. In *Alcohol*, certainly, that very subtil limpid Vapour, which is collected in the Bell, whilst the Alcohol is burning, is produced only from that watery part of the Alcohol that is not inflammable. All Ashes, Smoke and Soot, therefore, that are mix'd with inflammable substances, consist solely of Water, Salt, or Earth, nor of any thing else in nature, that we are acquainted with.

Whence
arise Smoke
and Ashes?

5. In the fifth place, we learn farther, that the quantity of Smoke, Soot, and visible Vapours in burning Vegetables, will be always so much the greater, as they contain more Water, Salt and Earth, in proportion to their Oil and Alcohol; for this is found to be the case universally, as well as in the Experiments we have been making. That is to say, such Bodies, when they are on fire, yield some parts, which though they are attracted into the Flame, and agitated there with a violent rotation, yet will not be converted into that subtil evanescent matter, but will either be expelled upwards out of the Flame, or else will fall to the bottom. If you compare a piece of very green wood laid on the Fire, with another in the same circumstances, that is so moderately dried as to retain its Oil, you will easily see a demonstration of the truth of what I asserted.

What are
the less com-
bustible
parts?

6. Sixthly, we find it is possible, that the parts of a combustible Vegetable that are not inflammable, *viz.* the Water, Salt, and Earth, may so far exceed those that are, that the Alcohol, or purest Oil, will not be able to flame in the Fire, but only send forth a mere Smoke. Alcohol, if it is mixed with an hundred times its quantity of Water, will not take fire, tho' it is heated hotter than Alcohol is when it boils; and if it is thrown upon the Fire it will extinguish it. A piece of Wood that is very oily, but at the same time very green, and full of Water, yields a large quantity of Smoke, but no Flame.

In

In fat clayey Potter's Earth, there is an Oil, which will take fire when alone, though when it is united with the Earth in such a manner, that there is but a very small quantity of Oil to a very great one of Earth, it refuses to burn. And in every instance you examine, you'll constantly find this assertion hold true.

7. But, in the seventh place, I think there is nothing more remarkable in this affair than this, which has been already proved in the former Experiments, viz. that if Fire is applied to a combustible Vegetable, composed of combustible and incombustible parts, and so far exerts its power upon it, as to set the combustible part on fire, and at the same time, and by the same action, to minutely divide and agitate the incombustible one; then the Flame that is thus excited from the combustible and incombustible matter agitated together, will be much stronger than would have been produced by the combustible one, if it had been separated, and set on fire by itself. For we always find Flame to be so much the weaker, as the matter is purer of which it consists. The Flame likewise generated from such a mixture, will always be more unequal than that which rises from a simple inflammable Substance: and hence, such a fire always makes more noise whilst it is burning, so as sometimes by its crackling and flying about to be very troublesome. At the same time too it produces more Smoke, and a greater quantity of *Fæces*. The more incombustible matter now there is in any Body, the more violent will all these *Phænomena* appear, if you can but set it on fire, and make it burn.

The greatest strength of Fire rises from the parts that are not combustible.

8. But again, eighthly, it is universally certain, that the denser, closer, or heavier the incombustible matter is, that is united with the Oil, the stronger will the Flame and Fire be that are produced by such a Body, if set on fire. So that not only the solidest part of any particular Vegetable yields the strongest Fire, if compared with the rest, (for who, that wants a strong Fire, ever prefers the Flowers or Leaves of Trees to their solid Wood) but also of different Woods compared with one another, we observe those afford the greatest Fire that are most ponderous; those the weakest, that are lightest. Thus, for Instance, compare Cedar with Sallow, or *Sideroxylom* with Poplar, and you'll find the strength of the Fires they excite will be in proportion to their weights.

And the *Pabulum* that is heaviest.

9. But, in the ninth place, we must here have regard to the doctrine we laid down before, that no Vegetables will burn, 'till they are heated to that degree, which is necessary to make Oil begin to boil. Light ones, indeed, will grow hot with the same Fire sooner than heavy ones; and therefore these will soon take fire, but those more leisurely: And for this reason you see that nobody makes Matches with solid Oak, but with spongy Reeds, or something of that nature. But the sooner they take fire, the weaker will be the Flame; and on the contrary, the longer they are before they light, the stronger and more durable will the Fire be that is raised by them: And hence, of consequence, the heavier the Wood is that is to be burnt, the more pre-existent Fire is always requisite to set it on fire; and without this it will not grow hot, ignite, and kindle.

No *Pabulum* of Fire burns of itself, but by means of Fire.

10. In the tenth place, these things being considered, it follows, that in the burning of Vegetables, all the combustible parts are not consumed at once, but gradually, by the successive action of the Fire. And here, during the time that the Fire is thus acting, that combustible matter, which is purely inflammable,

Burns successively, and in order.

flammable, and consequently the lightest, always takes fire, is separated and changed first; for this sort grows very soon hot, is first put in motion, and is more easily extricated than any of the other. This being consumed, that matter is next agitated, heated, set on fire, and separated, that possesses the next degree of inflammability to the former. This then being likewise burnt away, that last of all begins to burn, that of all is the least combustible. And it appears by an infinite number of Experiments, that this ultimate combustible matter in Vegetables is a small quantity of Oil, firmly united to a great deal of fixed Earth. Hence, then, we see the reason why this Oil cannot be separated from this Earth, in close vessels, where there is no admission of fresh Air. And hence, likewise, we know that this last combustible matter will never yield a violent Fire; for whilst it is burning away, a small portion of the combustible Oil is gradually distributed through a larger one of the incombustible Earth; and hence it may be made red hot, and lucid, but will very rarely produce Flame.

And most at
one certain
time.

11. From what has been said, therefore, we perceive, in the eleventh place, that Fire which is raised by compound combustible matter, will be most violent when it is in the middle of its burning, *viz.* when all the elements are flaming in the most vivid manner: Whereas towards the end, if you would keep Fire up brisk, it is necessary to rouse it with a pair of Bellows; for then the earthy, saline, fixed parts, which are interspersed throughout, in the form of Ashes, always begin to damp the force of the Fire, which is now supported by a smaller quantity of Oil.

Weak in
Alcohol.

12. In the twelfth place, we are farther certain, that the purest Flame of all, *viz.* that produced from mere combustible matter, without the mixture of any other particles with it, will never yield a very strong Fire; for it appears on the contrary, from former Experiments, that the purest *Pabulum* always produces the weakest.

What the in-
combustible
part does in
Fire.

13. Hence, therefore, contrary to the common opinion, we infer, in the thirteenth place, that the strength of Flame depends as much, nay, perhaps more, upon the incombustible elements in the burning matter, than upon those that are in reality truly combustible. And therefore the quantity of Fire in Flame raised from combustible Bodies, is more collected within the compass of this Flame, by the rotation of the immutable corpuscles that are mixed and whirled about with the rest, than by that fine volatile simple oily substance, that is agitated likewise by the Fire, in the same space.

Hence a
two-fold
matter of
Flame.

14. In the fourteenth place, then, why may we not suppose, that there are two causes exerting their united forces in material Fire; the first, elementary Fire, and its proper simple *Pabulum*, *viz.* perfectly pure Alcohol; the second, other kind of particles dispersed through the Fire thus produced, and which one would call pure Fire, which, though they are not able to sustain elementary fire of themselves, yet being agitated in the former pure Flame, excite a violent action by means of their vibratory motions, which is very often much greater than could ever be brought about by this agitating cause alone. That you may thoroughly take my sense, Gentlemen, please to reflect upon half an ounce of Gunpowder set on fire in the open Air; in this case, you know, a Flame will burst forth on all sides, and be over in a moment: But, now, if you put the same into a narrow cylindrical Tube, with some Bullets over it, and so fire it,

it

it will then, by its own proper motion, force these hard thick Bodies out of the Tube, with an incredible *impetus*, hardly any of which was observed before in the Particles of Gunpowder, tho' they were, by being set on fire, reduced to their most subtil Elements. In the same manner, therefore, you conceive, that the hard incombustible Particles of Vegetables being swiftly whirled about, and vibrated in the rapid Flame, must of consequence add a vast deal of force to it.

15. In the fifteenth place then it appears, that the greatest strength of this Fire, may be rendered more intense by Water, Salt, and Earth, if they are intimately mixed with the combustible Matter, and with one another in this pure burning Fire; provided the force of this Fire is great enough to put these Bodies into a violent motion.

Whence
Fire is in-
creased.

16. We observe again in the sixteenth place, that some cause is absolutely necessary, and that there really is some cause which continues this Flame, or keeps in this Fire, when it is once kindled. And one effect of this cause, must be the keeping the *Pabulum* of the Fire whilst it is burning, closely apply'd to the Fire itself, so that they shan't be separated from one another, which otherwise would instantly happen from the proper power of the Fire. But again, the hard incombustible Particles too, that are agitated by the action of the former combustible ones, must be likewise confin'd by the same cause within the compass of the burning Fire; that these likewise may not fly off too soon, but be compell'd to remain in the place where they are mov'd in such a manner, as by this very motion to be continually expelled out of it: For unless this was effected likewise, all this matter must of consequence be immediately dispersed by the agitation of the Fire, and thus all the vibratory force of these Corpuscles within the sphere of the Fire, would be lost in a moment. Hence, therefore, it appears, that all Fire would be momentaneous, was it not for this uniting, applying, and compressing power. It is probable, however, that this cause which compresses these Bodies together, must not act with so much force, as to unite them into one immoveable Mass; for by this means the lighted Fire would instantly be put out: But such a pressure only seems requisite, that the grosser Particles, whether combustible, or incombustible, as they are agitated in the Fire, may successively disengage themselves in proportion, as others begin to be put into the same agitation. Now for this purpose such a cause appears vastly best suited, that acts with a reciprocal, oscillatory compression, and relaxation, itself all the while remaining perfectly fluid, and incapable of being consolidated. Such a one now is our Atmosphere, which perfectly surrounds us, and always compresses us. Before we proceed any farther, therefore, it is necessary to have a just notion what assistance the Atmosphere really gives towards the support of Fire; which I shall endeavour to explain as evidently as possible in the following manner.

The cause of
uniting Fire
with its
Pabulum.

Let us suppose a Fire kindled upon an iron Plate with the choicest Wood, and burning perfectly quite through, upon a Base a Rhineland foot square. Upon this Base then there presses such a weight of the Atmosphere, as is contained in a prism of Air, whose Base is of the same magnitude. The weight, however, of this Prism, appears by the Barometer, to be different at different times; tho' the excess of its greatest weight above its least, is scarcely ever more than one tenth part of the whole. Let us imagine then the Atmosphere at this

The Phy-
sical manner
explained in
a common
Fire.

time to be heaviest, that is, the Mercury to stand at the height of 30 inches in the Barometer. Hence, if we suppose the specific gravity of Mercury, to be to that of Water, as 14 to 1; and a cubic foot of Water at the same serene time, to weigh 64 pounds *Troy*: Of consequence, the pressure of the incumbent Atmosphere upon this square Base, will be equal to the weight of 2240 pounds *Troy*. This Fire-place, therefore, is pressed upon by this vast weight at this time. But in this very place, by supposition, there is burning a flaming Fire, which repels from it on every side, and elevates with an incredible force all this bulk of the Atmosphere that is in its way, and at the same time expells from the space in which it is burning, all the heavy matter of the Atmosphere; and hence, of consequence, must increase its weight. It appears then, from the doctrine of Hydrostatics, that the resisting Fluid of the repell'd Atmosphere will press upon every point of the burning Surface; which therefore will be as strongly compressed by this weight, as if it was confined in a Furnace so strong that it would not break with the weight of 2240. All the inflammable Particles, therefore, that are agitated in this Fire-place, by the force of the elementary Fire collected there, and all those Corpuscles likewise that are incombustible, but are put in motion by the action of both the former, as they endeavour to disengage themselves from the Fire, are repelled towards its center by this vast weight, and that constantly, and exactly, so much the more as the Fire exerts itself within more violently. Hence, therefore, you perceive, that the Elements of the Fire itself, and the Particles of the combustible Matter, must be applied to one another, and compressed together with this prodigious force, and at the same time must undergo a very rapid concussion, and circumvibration among themselves from the incredible expansion, and active power of the Fire. Must there not therefore be excited a prodigious attrition in this Fire among these solid Particles? And will not the compression of these to one another, whilst they are thus agitated, increase in proportion to the greater attrition generated by the Fire? But the Fire is continually acting upon the Atmosphere by unequal concussions, which always makes an equal resistance: And hence this collection of Fire is beat upon by the continual return of the Atmosphere, with as much force, as if it was every moment struck upon with a Hammer of 2240 pounds. But we are farther certain, that the Air boils very violently over Fire, as one may perceive by exposing a live Coal to the Solar Rays, and then looking upon it towards the Sun, and hence the *subfultus's* of this very elastic Fluid, boiling thus strongly, must be still so much the more violent and frequent upon this Fire. If now, in any part of this burning space, the Fire yields less resistance than in the rest, then, the Air being driven thither by the weight of the Atmosphere, must rush in with a prodigious violence, and being instantly rarefy'd, and repelled again, will produce a continual strong oscillatory motion round the whole compass of the Fire. So long therefore as there remains Fire enough in this Fire-place to excite a Flame with its proper *Pabulum*; so long as the other incombustible Particles can be forcibly agitated by the action of the Flame; and so long as they continue to be pressed together by the weight of the Atmosphere, that they are not able to extricate themselves: So long the attrition excited in this space, will be so great, as to collect such a Fire here, as is sufficient to continue the like Flame. But on the other hand, as soon as ever the active elementary Fire, the true inflammable

Pabulum, or the other groffer hard immutable Particles that should be agitated among the other, are wanting, then the Fire presently grows weaker, and goes out: If the pressure of the aerial arch too is by any means lessened, or made less ponderous, the Fire immediately likewise loses its strength; and if it happens to be diminished to a very great degree, then the Fire, *Pabulum*, and other Particles, instantly fly asunder, and are dissipated. Hence in Boyle's *Vacuum*, all Flame, and then sparkling Fire, soon goes out; as there is nothing there to keep the Particles apply'd to one another. And from the same principles we see the reason why a moderate Wind very much increases the force of Flame; for it is then affected in the same manner, as if it was compressed by a heavier Atmosphere. If the Wind, indeed, blows so strong upon the Fire, as to destroy this arch of Air that surrounds it, the Flame will, then, be extinguished in an instant; tho' perhaps the next moment it will be raised again by the same blast that blew it out. Hence, therefore, if you blow a Fire with a pair of Bellows, so as not to put it out, by breaking this arch with the too great force of the Wind, the application of the Particles to one another, will by this action be stronger, and consequently the Flame more violent. But if two large pair of Bellows are placed in an opposite direction, and blown strongly upon the same Fire, then the Flame, excited by this means in the middle of them, will be prodigious intense, fit for fusing of Metals, and other Operations that require a violent Heat. This you may see at any time among your Workers in Gold, and other Metals. And from these Principles we see, lastly, why Fires burn more fiercely than usual, when the Air is contracted by a very sharp Frost; for then, the aerial Arch surrounds the Fire proportionably closer, and confines it more powerfully, and by this means prevents the Corpuscles, that are flying about and torried in it, from extricating themselves, till by the long continued action of the Fire, they are reduced to such a subtlety, as to be able to pass through the Air itself, and so to make their escape. But at the same time, likewise, the Fire exerts itself with the greatest force in its upper parts, and less about the circumference of its Base; and hence the Air finding there the least resistance, presses both the Flame and Fire upwards; and since the Fire is most condensed, and consequently strongest in the middle, hence the Flame will rise higher in the middle than on the sides where the force of the Fire grows gradually weaker; and of consequence will dispose itself into a pyramidal figure. But as soon as ever now the Surface of Fire is surrounded with such a Body as cuts off the communication with the Air, then the Fire of the *Pabulum*, and the agitated Particles, soon lose their motion, the Flame goes out, and the Fire itself is soon extinguished, except you remove the cover, and let in a free Air; then indeed, it will presently burst out into Flame, or at least may be raised to a bright, burning Fire.

17. But in the seventeenth and last place, if we carefully consider every thing that has hitherto been demonstrated, or delivered, it does not appear, that there is any Body in Nature, which being committed to elementary Fire, will in reality be converted or transmuted into Fire: For my own part, I have examined every argument that offers itself, and have not been able to find one that proves it. Hence, therefore, I dare not by any means assert, that either Alcohol, Oil, or any other Matter, becomes pure Fire by being burnt. I confess, indeed, that perfectly combustible Bodies are so changed in Flame, as to

The *Pabulum* of Fire does not become Fire.

get

get beyond the reach of our present perception ; but if we would have a proper regard to truth, we must not hence absolutely assert, that they are therefore converted into Fire itself.

Of the Pabulum of Fire in the Animal Kingdom.

Combustible Matter from Animals.

Having thus then carefully treated of the combustible Matter discovered in the Vegetable Kingdom, we come now in the next place to examine that which is contained in the Animal one. But here, as every one knows, that the Bodies of Animals consist of Vegetables reduced by their concoctive powers to proper nourishment, hence this head likewise is almost intirely exhausted in our History of Vegetables. And indeed, if we will credit Historians, the humours of the animal Body have sometimes been advanced to that prodigious subtil oily nature, as to take fire like Alcohol, and yield a weak pure Flame. We have accounts too of Flames kindling about the exhalations of Men's Bodies ; and *Helmont* takes notice, that the Wind of the Bowels being discharged upon a Candle, actually burned, and was converted into Flame. These things, however, if they are true, certainly happen very seldom. As for the other Oils of Animals, they differ hardly any thing in respect of their inflammability from those of Vegetables, and therefore the repetition of the Observations already laid before you, will here be needless. In these likewise we discover Water, Spirits, Salts, Oils, and Earth : And the nature, preparation, depuration, and effects of them in the Fire, are perfectly the same in Animals, as they are in Vegetables. If you'll please therefore to recollect what we have before delivered of the latter, and apply them to the former, the doctrine of these too I think will be sufficiently evident. You may possibly, indeed, surmise, that the *Phosphorus* procured from Animals, is an instance of some other inflammable Matter in Animals, than what is observed in Vegetables : But this may likewise, by the chemical Art, be extracted from the pinguious Coals of burnt Vegetables ; especially if they are of that kind, whose Juices very nearly resemble the Humours of Animals, as has long ago appeared in the Mustard. Any farther inquiry therefore upon this head, I think, is absolutely unnecessary.

Of the Pabulum of Fire in the Fossil Kingdom.

It is particularly remarkable now, that the very same law of combustibility, which we took notice of in the two former, holds true likewise, even in the class of Fossils. For here it is observed in the same manner, that the Oils alone are inflammable, the other parts not at all ; and that all these Oils likewise yield so much less Smoke, Soot, and Ashes, as they are more subtil and lighter ; and on the other hand so much more, as they are thicker, and more ponderous. Possibly in these too, there may be something that almost arrives to the subtlety of Alcohol ; tho' at present, I confess, I don't know that ever any body has discovered an Oil in them that would bear to be diluted with Water.

Naptha like Alcohol.

I have read, indeed, of Fluids sometimes distilling from rocks, that by the application of a lighted torch to them, would take fire, flame, and burn ; and have likewise met with accounts of Streams running from Fountains, that in the same manner might be raised into Flames : But whether the same Liquor that would thus take fire, would bear to be mixed with Water too, the persons

sons that mention these things take no notice. As for the *Naptha* of *Babylon*, Historians tell us, that that was so subtil, volatile, and easily inflammable, that rising, and being dispersed through the Streets, it would take fire from the Torches that were carried about in the night, so that it seemed as it were to burn spontaneously, covering all the Surface of the Ground with a blue Flame that was not very strong, and but little pernicious. This Liquor, therefore, on account of its exceeding subtilty, seems to come very near to the nature of Alcohol; for the same thing possibly might happen to our Alcohol, if it was distributed about in that hot country, in the same manner as we saw it take fire by the application of a lighted Match to its Vapour, when it exhaled into the cavity of the Bell. As it is hardly possible, however, to procure this sort of *Naptha* genuine, at any price, hence we can scarcely come at any certainty about it: As for that which is commonly sold about under that name, it has never any such degree of inflammability, but is always thicker, and more tenacious.

Petroleum is likewise very subtil, but no ways comparable, either to the *Naptha* of the Ancients, or the Alcohol of the Moderns. This, however, if it is depurated by proper distillations, grows gradually more subtil, and sooner inflammable, tho' it at last still remains an Oil, nor ever is reduced to Alcohol. And here again, as we observed in Vegetables, the finer, subtler, and lighter the oily combustible Matter of Fossils is, they always yield so much less Smoke, Soot, Stench, and *Fæces*; but at the same time the Flame is always in proportion the lighter, purer, and weaker.

As for the inflammable Fossils that have a mixture of a gross heavy incombustible Matter in them, they always take fire with more difficulty, and require a strong blast of Wind, or Bellows to make them burn strongly; but then the Flame and Fire that is raised from them, is so much the more violent, as we see evidently in the burning of the fossil Coal: Such Bodies likewise emit an exceeding black, thick Smoke, (which has somewhat of a disagreeable smell, and produces a good deal of Soot) and leave behind them a large quantity of Ashes, which generally have an insipid taste, but are very heavy.

Lastly, amongst the fossil Bodies, that afford a *Pabulum* for Fire, there are some which consist merely of a perfectly combustible Oil, united with an exceeding acrid, acid Salt. By these you'll easily perceive I mean Sulphur: Whilst the oily combustible part now of this burns away in the Fire, the other very acid saline one (which exceedingly resembles that Liquor which is forced from Vitriol by an intense Fire, and is called Oil of Vitriol) is incombustible in the Fire, and being collected by itself in form of a vaporous Fume, and then suffered to cool, goes by the name of Oil of Sulphur *per Campanam*. If this is then accurately freed from the Water that is mixed with it whilst the Sulphur is burning, and thus rendered pure in its kind, it appears to be the heaviest of all Fluids next to Mercury, and the most acrid we are acquainted with. And hence it happens, that Sulphur will not yield Flame, 'till it is first melted, and consequently, made very hot; but as soon as ever the Flame is excited by the inflammable part, the very ponderous, corrosive, saline, acrid one, being agitated, attenuated, boiling in the Flame, and being hence driven outwards, produces at first in the Flame, a very violent Fire, tho' afterwards, indeed, when by the continued action of the Fire it is so divided, as to be able to break

E e

through

Petroleum
next to
Naptha.

Fossil Coal.

Sulphur.

through the Arch surrounding the Flame, it floats about freely in the Air, and produces a Vapour that powerfully inflames all the parts of Animals it comes at, and hence, if it is apply'd to their Lungs, quickly suffocates them. And as for other Bodies that are exposed to the Fumes that rise from burning Sulphur, they are by this means surprizingly altered, and that, differently, according to their particular natures, and the relation they bear to the acid, which is the most so of any we know of in nature. These effects now produced by the Fire of burning Sulphur, are generally ascribed to the elementary Fire, tho' very wrongly: For these ought to be perfectly distinguished, and it should be constantly remember'd, that these effects are partly to be ascribed to the elementary Fire partly to the combustible portion of the Sulphur, and partly to the Acid that is by this means rendered volatile. I don't think it necessary now to explain particularly what *Phænomena*, *Bitumens*, *Asphaltus*, *Pissapphaltus*, and *Pix Judæicus*, produce in the Fire; or what they suffer there. I believe this will be so easily understood, from what we have delivered already, that we need not stay upon this head any longer. It is sufficient to take notice, that in all these there is a mixture of pinguious fossil Oils, generally acid Salts, Earth, and frequently something metalline or rocky; and that in them all, that only is truly inflammable, which is of an oily nature. As for the other parts of the composition, they afford a sort of *Spicula* which fly about in these fires, and by their vibrations, surprizingly increase their violence, or give them some singular physical power upon some particular sort of Bodies. These then being dispatched, I think we have sufficiently treated of the nature of the *Pabulum* of Fire, for our present purpose. And now, therefore, from this whole History of Fire, we may fairly deduce the following Corollaries, as truths which have been evidently demonstrated.

Fire rare-
fies all Bo-
dies.

1. Simple, pure, elementary Fire, insinuates itself into, and rarefies all Bodies in the universe that fall under the observation of our senses, whether they are solid, fluid, or compounded of both.

When alone
always equa-
ble.

2. This power is so proper to Fire alone, that it is not common to any other Body in nature, that human knowledge is yet acquainted with. The effervescences, fermentations, and particular rarefactions of Bodies, do not prove the contrary.

3. This Fire, as distinguished by this property, is always present in every place, as well in the solidest *Plenum*, as in the most perfect *Vacuum*.

4. And this Fire is every where distributed in the most equable manner, 'till there arises some cause that is able to collect it, thus dispersed, into one particular place.

Collected by
attrition.

5. The first of these collecting causes, and perhaps the principal one, is the attrition of some sort of Bodies with one another.

Expands it-
self.

6. Fire from its own nature is moved equally every way; or at least, is spontaneously expanded in this manner.

7. It's possible, however, that this motion, or expansion of Fire, may be so determined, that it may be directed in parallel, or converging lines; and this is a second very common method, by which Fire is likewise collected.

May be de-
termined by
the Sun.

8. The principal cause that compels Fire, of itself thus undetermined, into a parallellism, is the Sun; for this Body is found to be of vastly the most consequence for this purpose.

9. The

9. The cause then, that makes these Rays of Fire, converge, and unite in a small space called a *Focus*, is either reflection, or refraction.

10. And hence again we have a third manner of collecting Fire.

11. The rapid percussio of the coldest Steel, against the coldest Flint, in the coldest place, and weather, will in a moment produce the most intense Fire: This therefore furnishes us with a fourth.

12. This Fire therefore does not any ways depend upon the Sun, with respect to its Matter.

13. It will continue, however, some while in Bodies, being united to them during that time.

14. And the time of its continuance, will be proportionable to the density of the Body with which it is united.

15. There is not, however, any Body yet known, that is able to retain Fire always, when it is once communicated to it.

16. This Fire now described in these 15 Particulars, is in reality that which every Body calls elementary Fire.

17. There is, besides this, likewise, as people generally imagine, another sort of Fire, which consumes combustible Bodies into something invisible, which is supposed to be fed, and supported, and is falsely believed to convert combustible Matter into Fire itself: This is thought to be produced, when Fire first existing, is apply'd in the open Air, to a proper *Pabulum*. And by this means we have a fifth manner of collecting Fire; and that, the most common of all.

Fire supported,

18. There is discovered, now, but one kind of matter in the Universe, which will feed Fire in such a manner, as to be so intirely consumed by it, that nothing will be generated by it, but pure, simple Flame, and nothing at all will remain behind, when the *Pabulum* is burnt away, and the Flame goes out: And this is pure Alcohol alone.

By Alcohol.

19. Other Bodies, however, being mixed with the true *Pabulum* of Fire, whilst they are agitated by and in the Fire, together with this *Pabulum*, are capable of considerably increasing its power.

And Oil, remains the same,

20. Upon the kindling a common Fire, therefore, there is no Fire created, or generated *de novo*; nor is there any destroy'd when it is extinguished; nor does it undergo any alteration; nor perhaps has it any weight. The contrary, indeed, to this last assertion, seems to be grounded upon so many, and such solid arguments, that after Mr. Boyle had published his Treatise, *Of the Ponderability of Flame*, it was thought there was hardly any room left to doubt of it; much less still, since we have been favoured with those Observations of Monsieur Homberg, concerning the great weight that is added to incombustible Bodies, by pure elementary Fire, where there is not the least Mixture of any corporeal *Pabulum*; for by these, indeed, it seems plainly to appear, that elementary Fire may on a sudden be so absolutely concreted with Bodies, as to increase their weight very considerably. These Experiments, therefore, both candour and love of truth, oblige me to lay before you. First, then, Mercury, that was perfectly depurated by the help of Metals, and thus rendered more liquid than the native, being for a convenient time digested in a pure Vessel by the Flame of a Lamp, was converted into a black, white, or red powder, and in the operation was somewhat increased in its weight. Secondly, the famous *Du Clofus*,

Nor becomes heavy.

demonstrated before the *Academy of Sciences*, that Antimony calcined in the *Focus* of a burning *Speculum*, weighed a sixteenth part more when it had been thus exposed to the Fire, than it did before, notwithstanding so much in the mean time was dissipated in form of Smoke. But the egregious *Homberg* prosecuting the inquiry still more accurately by the assistance of the *Focus* of *Tschernhausen's* Convex, directed into a hollow Vessel, seems to have made it much more certain, that true Fire may be united with Bodies; that by this union it will be concreted with them; that by this means it will produce with them a new Body perfectly different from the former, and add a very considerable increase to their weight. For this purpose, therefore, four ounces of powdered *Regulus Antimonii Martialis*, where exposed to the *Focus*, as it was called, of the great dioptrical Glass of the *Duke of Orleans*, at a foot and a half distance from the true *Focus*, and was there frequently stirred about with an iron Spoon, 'till it would not smoke any longer; for at the beginning, and for some time after, it emitted a large quantity of dense Fume. This Powder then, was found to weigh four ounces, three drachms, and some grains; so that it had gained about a tenth part of its whole weight. The same afterwards being exposed to the true *Focus* of the Glass, was instantly put in fusion, and by this means lost three additional drachms, and grains, together with an eighth part of the first weight of the *Regulus*. Hence, therefore, it should seem probable, that the *Regulus* lost half an ounce by the Fumes of the first calcination, and gained three drachms of Fire, and that this fusion afterwards took away those three drachms of Fire that were thus superadded. The Preparations of *Minium*, Quicklime, and other substances in the Fire, seem to evince the same thing. That this now was really the event of these, and some other Experiments of Mr. *Boyle*, I make no doubt; nor do I in the least call in question the capacity of these great Men for making these Experiments, or their integrity in relating them. This, however, in the mean time, is certain, that a Mass of Iron of eight pounds, being made perfectly red hot quite through, did not acquire any additional weight. The degree of Heat, now, or quantity of Fire in the *Focus*, mentioned in M. *Homberg's* Experiment, which was a foot and half distant from the true one, was by no means so great as that of this Iron; and yet I weighed this Iron when it was red hot, and left it in the Scale till it was quite cold, and there was no alteration in the weight. That calcination was performed in an iron Ladle, or an earthen Vessel, and the matter to be calcined was continually kept stirring with an iron Instrument: Hence, therefore, the quantity of Powder might be augmented. The true *Focus*, in an instant, is supposed to expell again the Fire that was thought to be united with the Antimony. But who can venture to assert, that this was actually Fire? All Bodies thus calcined in the same Fire, do not acquire the same increase of weight, but those only that abound with a corrosive Sulphur, as Antimony, Lead, Tin, Iron, and Orpiment. Hence, therefore, maybe, this external, or additional part, is obtained by the Sulphur's corroding, and rubbing of the Particles of the other Bodies, and thus mixing them with the Matter to be calcined. And as for the increase of weight that Bodies are found to acquire, when exposed to the Fire in glass Vessels, supposed to arise from the insinuation of the Fire into them, this is so inconsiderable, that it may possibly be ascribed rather to what may be communicated to them from the Glass, than to the Fire itself. These Experiments

Experiments certainly ought to be made on purpose, and with the utmost caution; as nothing is more easy here than being deceived. Left, however, I should be suspected of being too obstinate, or partial, in my opinion, give me leave to refer you to *M. Du. Hamel*, a Gentleman particularly careful in relating Experiments, in the *Mem. de l'Ac. Roy.* p. 14, 15. where you will see how very prudently he himself raises some difficulties after he has recited his Experiments. And there too you will meet with some other Experiments of the famous *Bouledue*, which almost evince the contrary.

21. It has appeared farther, that this elementary Fire may be increased in a particular place, to a prodigious degree; so that by this means, certain physical effects, not easily understood in any other way, may be produced, observed, and reduced to a natural History. This we see evidently in Dioptrics and Catoptrics; but more remarkably still when both their powers conspire in the same action. And of the effect of this Fire we take the more particular notice, because as there is here neither any heterogeneous mixture, nor any material *Pabulum*, hence the purest elementary Fire exerts itself alone, and thus plainly teaches us what is the proper power of simple Fire, when bodies are exposed to it. If we nicely examine, now, the effects of this Fire, we shall find they may be reduced to these two: First, both Liquids and Solids, that are volatile in the Fire, are dissipated by it in a moment; and secondly, almost all fixed Solids, that have hitherto been examined in it, run into Glass. The most intense elementary Fire, therefore, that has ever yet been discovered, either dissipates, or vitrifies. But, as I have often observed before, the utmost that we know of this Fire, is only what we are able to learn from the greatest degree of it, that we can excite, by the assistance of those Arts which we are at present masters of; and therefore, as in the nature of things it may by collection be increased, and rendered more intense through an infinite number of degrees, we must not imagine, that the possible action of Fire is as yet determined. On the contrary, certainly that force of Fire which is with us at present the greatest, is scarce, as one may say, a beginning of what may possibly be generated. Since, then, we see in that small increase of it, which is contained betwixt the greatest Cold and the Heat of that *Focus*, which is produced by the union of *Vilette's* and *Tschirnhausen's* together; I say, since we see, even in this small extent of augmented Fire, so many various, singular, and surprizing *Phænomena*, who can so forget himself as to think, that the Doctrine of the power of Fire upon Bodies is as yet exhausted?

22. It is certain farther, that if this elementary Fire is collected in a particular place, let the cause be what it will, it may there be supported, by the help of proper *Pabulum*; which is always either Alcohol, or Oil procured from the animal, vegetable, or fossil kingdom. But again, this Fire being thus collected in this place, and supported by this *Pabulum*, may there likewise be prodigiously increased, by a greater weight of the incumbent Atmosphere, acting freely upon it; by a large supply of oily *Pabulum*, very strongly and intimately united in a proper quantity, with other very heavy Bodies; and by the action of a great many very large Bellows, blown swiftly, and so disposed as to unite their force in the center of the Fire. Now the ultimate effect of the greatest Fire of this kind that we are hitherto acquainted with, is, in Animals, and Vegetables, the production of Phosphorus; in Vegetables, the making of

May be
rendered
vastly intense
by collection.

In various
manners.

† Is not the
fusion of Iron
greater? See
p. 25.

of Glafs; in Fossils, the fusion of † Gold, which remains in this Fire, without suffering any alteration.

23. Having thus, then, explained to you the physical methods I am acquainted with, by which Fire may be collected and supported in any place, it remains now that we say something of that other most common and efficacious one, by which the same thing is effected, viz. the mixing different Bodies with one another, which affords us abundance of very extraordinary *Phænomena*. Of these, however, as there is an infinite number, it is impossible to mention them all, though it is necessary to touch upon some of them.

Of the Heat arising from the mixture of vegetable Substances.

The Philosophers have long ago observed, that upon mixing certain different Bodies together, there often suddenly arises a very considerable degree of Heat or Cold, evidently depending upon this cause: And this Heat or Cold, they took notice, did not exist in the Bodies before this Mixture, nor continued any longer than till this was perfectly compleated, the Bodies then returning again to the very same temperature they were of before. The history of these the Lord *Verulam*, in particular, began, and *Boyle* and *Hook* carried to greater perfection: A few instances I shall here exhibit before you. Give me leave, however, first to explain to you the instruments that have been contrived on purpose for these Experiments, and which I shall make use of as I proceed. ABCD is a large Thermometer filled according to Art with ting'd Spirit of Wine, which is fixed in such a manner to the board it is let into, that the lower part of it MBA may be free of the Wood, and thus the Vessels, in which the Liquors to be examined are to be mixed, may receive it without any difficulty; and to render the numbers on the side sufficiently visible, the board is painted very black, and these white. The Vessel, then, with the Liquid is to be placed in such a manner under this Instrument, that the whole Thermometer AB may be within the Vessel, and in the Liquor; and then let the other Liquor be poured in, and let them be well stirred about with a glass Pipe, that they may be intimately mixed together; and by this means the Thermometer will immediately indicate the alteration that is produced, with regard to Heat or Cold, from this mixture. By this instrument now, and this method, you will be able to see perfectly the whole Affair at a distance; let us now therefore begin.

Pl.V. Fig. 1.

EXPERIMENT I.

In this vessel are two ounces of rain Water, rendered exceeding pure by distillation in a tall Glafs with a gentle Fire. In this other there is the same quantity of common Spirit of Wine. Both these Liquors, you shall see me examine with this small Thermometer; and you observe they have both 44 degrees of Heat. One of these, now, I put under the Thermometer just explained, which stands likewise at the same number 44. I'll now mix these together at once, and stir them about with this cold glass Tube; and you perceive evidently, that they have acquired such a degree of Heat from this mixture as to make the Thermometer rise to the degree 52. Hence then we learn, 1. That this pure Water, and the Spirit of Wine, were in the Air equally hot before the mixture. 2. That the Air, Spirit of Wine, and Water, had before this mixture the same degree of Heat. 3. That if Air and Water,

or

or Air and Spirit of Wine, are mixed together, there will be no alteration produced in their Heat. 4. That upon mixing Spirit of Wine and Water together, they grow hot immediately, but not from the Heat that was in them before, for they were both equally hot or cold. 5. But from some other physical cause, which was latent in them, and which, upon the mixture, produced this Heat. 6. That this Heat, that is thus generated from this mixture, lasts no longer than during the time in which it is performed, and then ceases, tho' you agitate them much more forcibly than you did in mixing them. 7. That the whole physical cause, therefore, of the production of this considerable Heat, is only the first application of the particles of the Spirit of Wine to those of the Water; and that Fire is instantly excited in the very contact, and disappears again presently after it. 8. That the Fire thus generated, or discovered by this mixture, is true elementary Fire; as its effect upon the Thermometer evidently demonstrates. 9. That a good deal of the Heat was destroyed, whilst the Thermometer was heating by the mixture to this degree.

EXPERIMENT II.

Observe, again, these two Vessels, one of which contains the same quantity of Water, as in the former Experiment, and heated to the same degree, viz. 44; the other the same quantity of pure Alcohol precisely as hot as the Water; the Thermometer likewise, as before, standing at the degree 44. These then being mixed in the same manner as in the preceding Experiment, the Thermometer rises to the degree 62. Hence, then, we infer, 1. Every thing that was taken notice of in the first Experiment. 2. That Water and Alcohol, by being mixed together, grow very hot, much hotter than Water and Spirit of Wine. 3. That the cause, therefore, of this greater Heat depends intirely upon the proportion of the Alcohol, to that of the Water with which it is mixed. 4. That Water, by being poured upon Alcohol, causes a greater quantity of Fire to enter into the Alcohol, than was in it before, though this so much resembles Fire; for Alcohol mixed with Alcohol produces no heat at all; Water mixed with Alcohol does. 5. That the less Alcohol, the Water, which is thus mixed with the Alcohol, has in it, that is, the purer the Water is, the more Heat it will generate in the Alcohol; and the reverse.

EXPERIMENT III.

I take now two ounces of alcalifated Alcohol; and the same quantity of pure Water. Before they are mixed they are equally cold, viz. 41 degrees; as is likewise the Thermometer: The mixture gives 54 degrees of Heat. Hence we see, 1. The truth of what has been asserted under the first and second Experiment. 2. That Water and alcalifated Alcohol grow hotter upon mixing, than Water and Spirit of Wine; but less so, than Water and pure Alcohol. 3. That the cause therefore of Heat in these mixtures is owing wholly to the Alcohol, and pure Water.

Compare with these the Observations of the famous Mr. Geoffry, in the *Mem. de l'Ac. Roy.* 1723. p. 53. These Experiments furnish us with some Bodies, and those pretty remarkable ones too, by which we may bring about
 2 this

this generation of Heat; and in these, besides what has been observed already, I think this deserves to be particularly taken notice of, that in them all the Heat is only generated in the very point of mixing, nor is any greater degree perceived afterwards. And hence, the quicker this is performed; the Heat that is excited by the same quantities will be always the greater; and on the contrary the less, the slower, and more successively. For as soon as ever the mixture is so compleated, that all the particles of the Water are united with all the particles of the Alcohol, in vain will you expect any farther increase of Heat. Nor will a violent agitation of the mixed Liquors be then of any consequence; for the degree of Heat will afterwards not only be no greater, but in those three Experiments, when the mixture is once perfectly finished, it begins immediately to remit, and a succeeding Cold increases every moment, till the Liquor is soon reduced to the common temperature of the Atmosphere: And in the same manner the Experiments I have tried have always succeeded. Hence, therefore, we infer, 1. That at the point of time, in which the Elements of the Water and Alcohol come into contact, there arises some physical cause which attracts the Fire thither. What this cause is, it is not easy to determine. This, however, we observe, that at the time particularly when the mixture is first made, the Liquors, which were before clear, lose their transparency; and that this opakeness continues so long as the Heat is generating, which being quite compleated, they perfectly regain their pellucidity. And again, precisely at the very same time, there is produced a vast number of very small bubbles, which move among the mixed elements of the Liquors, presently burst, disappear, and are again renewed; but when once the Heat is generated, are never observed after. Whether, now, these Bubbles do by their motion produce this Heat, or rather, whether they themselves are generated by the Heat's rarifying the aerial particles interspersed through the Liquors, is hitherto matter of doubt. 2. This, however, we learn certainly from those Experiments, that this Heat does not depend upon the united substance of both Liquors, but upon some other cause, which exerts itself only in the very first union of the elements together. On this Account, therefore, it seems very probable, that all the Heat thus generated exists there but the least instant of time; which certainly is very remarkable. Nor does Gunpowder, perhaps, burst sooner into Flame, by the application of a spark to it, than this Heat arises upon the mixing of these Liquors. 3. The more accurately, and intently, therefore, we examine this affair, are we not so much the more at a loss to find out what this in reality is, which thus collects this Fire? Is it the reciprocal attractive power of these elements, by which, when they approach one another, they rush into contact, and by this Collision excite little Fires? Or does an alternate attraction, and repulsion between these elements, produce a very swift attrition among them, and by this means generate Heat, the attrition ceasing again, when the particles are equally distributed among one another, are at rest? 4. Since this Heat arises in Water and Alcohol, upon their being mixed together, whether they had this or that particular degree of Heat, when they were separate, and the new degree is so much greater than that before the mixture; hence, therefore, Alcohol, by being mixed with the Water of our Blood, may, to a certain degree, and for a certain time, heat it

very suddenly, tho' afterwards, however, it will in this respect have no farther effect upon it. 5. For this reason, therefore, Bodies that are cold from a watery dampness upon them, may be warmed by being rubb'd with Alcohol; and on these principles the effects of Baths and Fomentations made with Alcohol may be understood.

EXPERIMENT IV.

If the purest Water, and the most generous Wine are perfectly united together in the same manner, they don't discover the least sensible increase or decrease of Heat; there is something of Warmth, indeed, but it is so exceeding small, that it can scarcely be perceived. Hence it appears, 1. That Water and Wine are equally warm in themselves, and that they still continue of the same Warmth after they are mixed together. 2. That the application of Wine, therefore, does not heat any thing considerably more than Water. 3. That the Heat, of Consequence, that is perceived in a human Body from drinking of Wine, does not arise from any Heat that pre-existed in the Wine, and is then communicated to the Fluids, but is owing to its *stimulus*, by which the velocity of the Blood being increased, and a greater attrition excited between the Vessels and the Fluids, Fire of course is attracted thither.

EXPERIMENT V.

From this quick mixture of Water with the distilled Vinegar of the strongest Wine, which were perfectly of the same warmth, you don't perceive the least degree of Heat produced, but they remain exactly as they were before. Hence, therefore, 1. The Heat of Water and Vinegar is the same, nor does there arise any alteration in it, by mixing them together. 2. The refrigerating power, therefore, of Vinegar in the human Body, so extolled by the Physicians, must depend intirely upon some other causes than a Cold that is natural to the Vinegar.

EXPERIMENT VI.

These two Vessels contain equal quantities of Oil of Tartar *per Deliquium*, and pure Water, which are both exactly as warm as the external Air; and you perceive evidently, now I have perfectly mixed them together, they retain precisely the same degree of Heat. Hence, 1. That Liquor, which of all Fluids appears to us the most fiery, is in reality no hotter in itself than pure Water; nor is Water any ways cooler than that very heating Liquor. This assertion, to a person unacquainted with this Experiment, would seem an extraordinary paradox; but the Truth of it, however, is undeniable. 2. This Liquor, which is esteemed so igneous, if it is mixed with Water, don't at all lessen its Coldness. 3. When a fixed fiery alcali is once dissolved in such a quantity of Water as is sufficient to dilute it, it will not afterwards generate Heat in any other Water. 4. Neither, therefore, can this liquid Alcali excite any Heat in this respect, by being mixed with the Water of our Blood.

EXPERIMENT VII.

I have here Water, and distilled Oil of Turpentine, which now they are separate, are just as warm as the Air at this time; and though I now mix them together as intimately as possible, yet they don't generate the least degree of Heat. Hence again, 1. Distilled essential Oil, which heats the human Body to such a degree, and defends it so happily against the ill effects of Cold, has in reality no more Heat in it than simple cold Water. 2. This Liquor, though in a great many of its properties it comes so near to Alcohol, yet communicates no Heat to the Water it is mixed with, though Alcohol, by being mixed with Water, excites a very considerable degree; which extraordinary *Phænomenon* makes probable the doctrine we before laid down, when we assigned the first contact of the elements of the Water and the Alcohol, as the principal cause of the Heat that is thus generated. 3. This Oil, therefore, again, cannot add any Heat to the Water of our Blood, by being mixed with it.

EXPERIMENT VIII.

The most certain mark, perhaps, of Alcohol's being perfectly pure, is its suffering itself to be intimately mixed with distilled Oils, by simple concussion; for if it contains but the smallest quantity of Water, such a perfect mixture will not be possible. Some such Alcohol I have here, which is equally warm with this very pure ætherial Oil of Turpentine, and the Air at this time. These, now, I'll mix together, and what do you imagine will be the consequence? You see they unite intimately with one another, just as Alcohol does with Alcohol; and that there is not the least variation from the Heat which both the Liquors had before the mixture. This, certainly, persons generally would not have expected: Nay, even those who were acquainted with the former Experiments would imagine, that some degree of Heat must arise from the intimate contact of the Oil and Alcohol. We here see, then, that the particles of Alcohol will bear to be as perfectly and equably dispersed through the Oil, as they will through Water; but that no Heat, however, is generated by this means. Alcohol, therefore, will not excite any Heat by being mixed with our Oils, though it will if it is mixed with the Water of our Blood. What new and unexpected discoveries do we make in natural Philosophy, when we designedly apply Bodies to one another! Let us, therefore, prosecute this method as much as possible.

EXPERIMENT IX.

Distilled Vinegar, and Oil of Turpentine, which now they are separate, are equally hot with the Air, and one another, viz. * 44 degrees, I thus gently and gradually mix together; and by a successive augmentation, they increase the heat to the degree 45. Here therefore, 1. The Vinegar and the Oil are of themselves equally hot. 2. Some Heat arises from their being mixed together. 3. Hence the power that Acids have of generating Heat with oily Bodies begins to discover itself, tho' they are so but in the smallest degree, for as *Monf. Homberg* has demonstrated the strongest Vinegar don't contain above one eightieth part of pure acid. *Mem. de l'Ac. Roy, des Sc. T. 1. p. 52.* 4. Vinegar,

* Should not
this be 42?
See the next
Experiment.

Vinegar, therefore, will generate some Heat with our Oils by being mixed with them. 5. And in this respect Vinegar differs from Water.

EXPERIMENT X.

The same Vinegar and Alcohol, which I made use of before, and which are qually hot with the Air, I now mix together; and you perceive what a remarkable Heat immediately arises: For from the degree 42, in which they were before the mixture, they now raise the Thermometer to 52. Hence, therefore, 1. Alcohol and Vinegar are separately equally hot. 2. A very considerable Heat is generated by their being mixed together. 3. Alcohol grows hot with Vinegar, so much more than it does with Oil.

EXPERIMENT XI.

Oil of Tartar *per Deliquium*, and Oil of Turpentine, separately equally hot, viz. 45 degrees, upon mixing, raise the Thermometer to the degree 48. Hence, 1. These Liquors of themselves have the same degree of Heat. 2. In mixing, they grow considerably hotter than they were before.

EXPERIMENT XII.

The same Vinegar and Oil of Tartar *per Deliquium*, which separate were eqally hot, viz. 46 degrees, being expeditiously and accurately mixed together, continued exactly in the same degree of Heat: But in this Experiment I made use of 3 parts of Vinegar, and 1 of Oil. Hence, therefore, it appears, that Fire is not collected by the Union of opposite Salts.

EXPERIMENT XIII.

Alcohol, and Oil of Tartar *per Deliquium*, that were as hot as the common Air, by being intimately mixed together, increased their Heat from 64 degrees to 68.

EXPERIMENT XIV.

I have in this Phial some of the same Alcohol, equally hot with the Air at this present time, viz. 47 degrees. Into this, now, I pour some pure, dry, fixed alkaline Salt of Tartar; upon which the Liquor in the Thermometer rises to the degree 51.

EXPERIMENT XV.

With this pure Water, I mix one third part of the same Salt of Tartar; and the Thermometer rises from the degree 47 to 57.

EXPERIMENT XVI.

I now put one part of the same Salt of Tartar, to three of the Vinegar we made use of before; and the Thermometer rises from 43 to 49.

EXPERIMENT XVII.

With three parts of Oil of Turpentine, I mix one of the same Salt of Tartar; and the Thermometer rises from 43 to 48.

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From

From what has been hitherto laid down, then, we learn, 1. That the simple Bodies, which are chemically extracted from Vegetables, have really the very same degree of Heat in them, *viz.* that of the common Air, at the time they are examined. 2. That some of these acquire a greater Heat by being mixed together; which generation of Heat, however, continues no longer than during the time of the mixture, which being perfectly completed, the new degree of Heat does not remain, but they gradually return again to the temperature of the common Air. 3. That this production of Heat, therefore, does not depend upon the Substance of the united Bodies, but only upon the union of them at that time. 4. That Alcohol and Water are the principal of the vegetable Fluids, which have that power of generating Heat, which has been described. 5. That Salt of Tartar and Water are the chief among the Solids and Fluids, which, by being mixed together, produce the greatest degree of Heat. 6. And that next to these, Alcohol and Salt of Tartar, are the most efficacious. These, then, being thus dispatched, let us, with the same care proceed to examine the parts of Animals.

Of the Heat arising from the Mixture of animal and vegetable Substances.

EXPERIMENT I.

Fresh Urine, well concocted in a healthy Body, being exposed to the Air, soon acquires the same temperature with that at that time; and if it then, as you see, is mixed with an equal quantity of Water, it makes no alteration at all in the Thermometer.

If it is mixed with Alcohol, the Heat increases from 38 degrees to 49.

With Oil of Turpentine it suffers no alteration.

With Salt of Tartar the Thermometer rises from the degree 38 to 39.

With the strongest Vinegar no alteration.

Nor with Spirit of Urine.

With Salt of Urine it descends two degrees.

With Spirit of Nitre it rises from 38 to 43.

With Spirit of Salt, from 39 to 43.

With Oil of Vitriol, from 39 to 54.

EXPERIMENT II. *After various manners.*

The Urine of a healthy man being kept a good while in a close Vessel, and by this means being very much putrified, will have the same temperature as the Air at that time; and if it is then mixed with Water in equal quantity, will cause a small descent in the Liquor of the Thermometer.

Being mixed with Alcohol in the same manner, the Heat increases from the degree 38 to 45.

With Oil of Turpentine, no alteration.

With Salt of Tartar, the Thermometer descends from 38 to 36.

With the strongest Vinegar, ascends from 37 to 38.

With Spirit of Urine, descends from 38 to 36.

With Salt of Urine, from 38 to 32.

With Spirit of Nitre, ascends from 38 to 40.

With

With Spirit of Sea Salt, from 38 to 41.

With Oil of Vitriol, from 38 to 45.

EXPERIMENT III. *After various manners.*

Salt of Urine procured from fresh Urine by distillation, without the addition of any thing but Sand, being mixed with Water in the manner often described, made the Thermometer descend from 40 to 38.

With Alcohol, it ascends from 40 to 41.

With Salt of Tartar, from 40 to 45.

With the strongest Vinegar, it descends from 43 to 41; but with the same inspissated to the consumption of one half, ascended from 42 to 44.

With Spirit of Nitre, from 43 to 60.

EXPERIMENT IV. *After various manners.*

With a pretty strong, volatile, alkaline Spirit, prepared from equal quantities of *Sal-Ammoniac*, and Salt of Tartar, I mixed an equal quantity of Spirit of the strongest Vinegar, when they were both equally hot with the Air; and the Liquor in the Thermometer rose from the degree 44 to 48.

With the strongest Vinegar, inspissated to one half, from 46 to 47 $\frac{1}{2}$.

With spirit of Salt distilled with Bole, and afterwards rectified, from 46 to 64.

With Spirit of Nitre, distilled with Bole, from 46 to 82.

Of the Heat generated by the mixture of fossil Substances.

EXPERIMENT I. *After various manners.*

I here take 3 ounces of clean Water, 47 degrees hot, and put to it 1 ounce of pure Nitre reduced to powder; and the Liquor in the Thermometer descends to the degree 36.

I mix 1 ounce of pure Borax with 3 ounces of Water, 48 degrees hot; and the Thermometer falls to 45 $\frac{1}{2}$.

With 3 ounces of Water, 46 degrees hot, I mix 1 ounce of Sea Salt; and it falls to the degree 43.

To 3 ounces of Water, 47 degrees hot, I put 1 ounce of *Sal-Ammoniac*; and it falls to the degree 28.

With 3 ounces of Water, 45 degrees hot, I mix 1 ounce of Oil of Vitriol not rectified; and it rises to the degree 60.

To 2 ounces of the purest Alcohol, 47 degrees hot, I add 1 ounce of Oil of Vitriol not rectified; and it rises to the degree 60.

With 3 ounces of distilled Vinegar, 46 degrees hot, I mix 1 ounce of Oil of Vitriol not rectified; and it rises to the degree 60.

Cerufs, by causing an ebullition with weak *Aqua Fortis*, makes it rise from the degree 44 to 57.

Tin, by causing an ebullition with weak *Aq. Regia*, makes it rise from the degree 44 to 56.

Filings of Iron, by causing an ebullition with *Aq. Regia*, make it rise from the degree 44 to 160.

A great many other Experiments I have made of the like nature, but am afraid I shall tire your patience. Give me leave, however, to observe, that if all the simple Bodies in the animal, vegetable, and fossil kingdoms were examined in this manner, beginning first with these of the same class, and carefully noting all the *Phænomena* that arise from the mixture of these; and afterwards proceeding to make the same trials upon the simples of different classes; we then should soon have a compleat and certain history of the Heat that is generated by the sole mixture of various Bodies with one another. But here let me caution you, that the Experiments thus performed before you, are not made with that care and accuracy, as they might and ought to have been, if we would have settled this affair nicely; but this the straitness of our time, and the fear of being tedious, would not admit of. And besides, as so large a number of you do me the honour of attending to these lectures, and I am willing you should all fairly perceive the event of the Experiments, I thought it proper to make use of such large Thermometers. But these, as you know, by having their large Bulbs immersed in so small a quantity of Liquor, must, by being affected themselves, make an alteration in the Heat or Cold produced in the mixture, and thus make some variation in the visible effect. These Experiments, therefore, for this reason, you must not look upon as very exact. If your own ingenuity should put you upon prosecuting these inquiries with greater accuracy, I would advise you to make use of those beautiful Thermometers of *Fahrenheit*, that are made with Mercury; which is the sort I made use of in producing the Cold with *Sal-Ammoniac*, which I some time ago gave you an account of. These have this great advantage, that they are exceeding sensible of Heat and Cold, and at the same time are so small, that they make very little alteration in the Heat of the Liquors to be examined.

Of true Fire generated in a cold Body, by the sole access of the Air.

The indefatigable industry of the Chemists is continually finding out something which former Ages were not acquainted with. Now among these discoveries, Gunpowder excepted, there is nothing more surprizing than those Bodies, which, whilst they are kept from any communication with the common Air, are as cold as others, but as soon as ever this has a free admission to their surface, presently take fire and flame of themselves, purely from this cause, without the accession of any other Body, any mechanical attrition, or the application of any Fire. These Bodies have obtained the name of *Phosphori*: Those alone I mean, here, by which Fire is really generated; not regarding the other, which only shine in the dark, and do not at the same time excite any Fire.

The Phosphorus of *Craffius*.

If the Juices of Animals, when they have first undergone a great degree of putrefication, are by the action of the Fire deprived of all their volatile Salt, and Oil, they leave behind them a kind of a Coal: If you mix this with three times its quantity of Sand, or powder'd Charcoal, or with two parts of Charcoal, and half a one of Alum; and then put it into a coated Retort made of crucible earth, and urge it with a reverberatory Fire, gradually increased to the greatest degree, and equably continued for a considerable time; and if at the same time you take care to dispose the Retort in such a manner, that the

the mouth of it shall touch some Water contained in the Receiver, which must be accurately luted; if you proceed, I say, in this manner, you will then with your last degree of Fire, after some Fumes, have a heavy, greyish matter, which will fall in grains to the bottom of the Water, will not dissolve in it, melts with Heat, and may by the assistance of it be formed into masses under the Water. This, which is called the *Phosphorus* of *Craftius*, *Kunkelius*, and *Boyle*, if it is kept cool under Water, may be preserved a great while without alteration; tho' if the Air by any means grows very hot, it will shine in the dark, even through the Water it lies in; but if it is openly exposed to but a warm Air, it then becomes lucid, and if the heat is pretty considerable, upon examination with a Microscope, you may perceive a constant ebullition in the internal parts, soon after which, it bursts into Flames, consumes, and leaves behind it an Oil of Vitriol, or a Liquor exceedingly like it in acidity and weight. This, therefore, is a new method of generating Fire, perfectly distinct from all the former. Does the Air, then, when it is pretty warm, at which time it is probable it is in a constant ebullition; I say, does the Air then, by its concussions, cause an attrition in the parts of the *Phosphorus*, and, by this means, excite in this very Mobile, but at the same time pretty fixed matter, some degree of Heat, then Light, and afterwards Flame? Certainly, if it is exposed to the Air in the greatest Cold, it scarcely shines, does not grow hot, and is far from being set on fire: But as soon as ever it begins to flame out, it can scarcely be extinguished. In almost every quality, and the *Analysis* of it by deflagration, it comes very near to the purest common Sulphur, but is of a softer consistence, more easily melted, and on that account is rather of the nature of Wax. In this respect, however, there is this difference between them, that *Phosphorus* boils and takes fire with a small degree of Heat. See *Boyle. Noëtiluc. Aer. Slare. Philos. Transf.* 1683. p. 1457. *Homberg. Mem. de Mathem. & Physf. Ann.* 1692. p. 74 to 80. *Nieuwentyt. p.* 520. *Hoffman. Dissert. Chem. Physic. p.* 336.

But there has been another and much more beautiful method discovered of ^{Igneous} ^{*Phosphorus.*} making a Matter, which upon contact with the Air, whether hot or cold, immediately generates Fire, and burns. This was first communicated to me by Letter, by the egregious *Homberg* of *Paris*, the 16th day of *April*, 1712, which was delivered me by the ingenious *Hasberg*, who at the same time added some considerable remarks of his own. Afterwards, when the method was rendered more easy, and less disagreeable, it was published in the *Journal des Scavans*, *An.* 1716. p. 60. And here give me leave to observe, that as the *Phosphorus* just now mentioned, owed its discovery to a crazy headed Alchemist, that was hunting after the *Philosopher's Stone* in *Urine*; so this which I am going to describe, was the invention of one of the same Sect, who was madly pursuing this occult Stone in 'human *Fæces*. The Operation is as follows. Take the Flesh of a tender Animal chopp'd very small, or any of its Juices, or even its Excrements; put this Matter into an iron Frying-pan over a moderate Fire, and with an iron *Spatula*, keep stirring it about 'till it is reduced to a dry black Powder: Or instead of this, you may treat in the same manner any soft Vegetables, any sort of Meal for instance, it signifying very little, which of these you make use of. Take 1 part then of this black torrifed Powder, and rub it with 4 parts of crude Alum, 'till it is brought to a very fine Powder. Put this

this into an iron Frying-pan, and roast it over the Fire, all the while stirring and rubbing it with a *Spatula* almost red hot to keep it in form of a Powder; and whenever the Alum is melted, and with the Powder runs into lumps, these must be immediately rubbed to pieces, and the whole must be thus kept in motion, till the matter will emit no more Fumes, but is totally converted into a fine, dry, fix'd Powder, that is perfectly black. Take then this dry black Powder, and put it into a clean dry glass Bolt-head, with a slender Neck, filling the Body two thirds full; and let the mouth of the Glass be covered with a Paper, so that the Air may pass in and out freely; and that the Fumes may get readily out of the neck of the Glass. Put this Bolt-head into a Crucible, and so guard it with Sand, that the sides and bottom of the Crucible may be well secured from touching the Glass; and let there be left so much room above the Sand, that you may easily look into the Body, and see whether the Matter contained in it, is red hot. Round the crucible then, with the Sand, and Bolt-head, dispose some burning Coals in such a manner, that it may be heated gently and by degrees, 'till it grows all over thoroughly hot; and then increase the Fire, 'till the Crucible, Sand, Bolt-head, and Matter contained in it, are perfectly red. When you observe this to be the case, keep up the Fire in the same degree for the space of an hour; and then, whilst the force of the Fire continues, close the Orifice of the Glass so accurately with Wax, that no Air can possibly get into it. This being done, let them all cool of themselves; and in the Bolt-head you will have a black powdery Coal, composed of the Powder and the Alum. If any of the Matter then thus prepared is thrown out of the Glass into the cold Air, it instantly takes fire and burns; but if it has once been exposed to it, it loses intirely this vertue. And this method of generating Fire seems the most surprizing of any we are acquainted with, as this matter will retain its power of exciting Fire for the space of three whole months, if it is kept from any communication with the external Air. In this Experiment, now, we have a true animal, or vegetable Coal produced by the calcining force of the Fire, and that an exceeding subtil one too, and consequently intirely fit to feed and support a spark of Fire when once it has received it; as appeared formerly in our History of Coal. This Coal too is rendered as dry as it is possible to make it; as appeared through the whole process: For if the least Moisture, nay even that which is dispersed in the Air, comes at the Powder, the success of the Experiment is intirely frustrated. And here we must observe, that all the Air, likewise, must be expelled by this excessive Heat: For at that time, the mouth of the Glass must be carefully stopped, when the greatest degree of Fire which the Glass can bear without melting, has forced all the Air out of its Cavity, and out of the Matter contained in it; for if by any means the Air can insinuate itself in afterwards, the Experiment will never succeed. In the mean time, by this protracted calcination, the Air, Water, and volatile acid Spirit must be expelled from the Alum likewise, (which seems to be a Lime-stone prey'd upon by Oil of Vitriol, and converted into a Salt) nothing at all remaining but a very strong Oil of Vitriol, fixed in the exceeding dry Earth. These Bodies now, which are vastly attractive of Moisture, grow hot upon the admission of Air, and this rushing into their empty Pores with the *Impetus* formerly computed, p. 130, will in an instant cause a most vivid attrition of its parts, and thus, perhaps,

perhaps, generate Fire, which being received on that very fine Coal, will be easily sustained and supported. But whether this, or something else, is the cause of this wonderful *Phænomenon*, this at least we are now a-days certain of, that, without any assistance of Fire, it is possible for the common Air, by simple contact only, to set fire to a cold Body in such a manner, that it shall by this means be totally consumed to Ashes, as certainly, as by any other Fire that we are acquainted with. But to the best of my knowledge, this last Experiment is the only one by which we can always effect it. Who then can pretend to set bounds to the power of Fire? Who, five and twenty years, would have thought such a thing possible? Or who can foretell those things that will be reveal'd to future ages? Should the Glass which contains this cold Powder be broke, and it should fall amongst Gun-powder, what would be the consequence?

Of Fire produced from cold Fossils by the help of Water.

If the fresh Filings of Iron, not yet rusty, are mixed with an equal quantity of very pure Sulphur, and they are strongly rubbed together for a considerable time, till they are reduced to a very fine Powder; then, this Powder, keep it ever so long in a dry Air, will continue cold, if you carefully secure it from all Moisture: But if you work this Powder with such a quantity of pure Water, as to reduce it to a stiff Paste; then, after some time, the Mass will grow warm, fume, puff up, grow hot, emit a black, hot, sulphureous Smoke, take fire, and flame: And after the Operation is over, there will be left a brown, black, fine *Calx*, by pouring Water on which, you may extract a kind of Vitriol from the Iron, exceedingly like the *Vitriolum Martis*, which in the common Method is prepared with Oil of Vitriol. If you take, now, a large quantity of each of these Fossils, for instance, 25 pound of Iron, and as much of Sulphur, and make them into a Paste, and bury it a foot under ground, after 8 hours, the Earth that is over it will begin to heave, send forth hot sulphureous Vapours, and burst out into Flames, and thus produces a true subterraneous Fire. *Hist. del' Acad. Roy. 1700. p. 52. Mem. p. 101.* And the reason seems to be this; the Sulphur being an inflammable Oil, concreted with the exceeding acid Oil of Vitriol; and Iron being a Metal, which will always dissolve in the Acid of Vitriol, and by this means generate a very great degree of Heat; hence, it seems probable, that when the very small Particles of these two Bodies are rubbed together, and thus brought into very close contact, and by the addition of the Water, are held still much more strongly together; I say, when this is the case, it is probable, that the Acid of the Sulphur begins to corrode the Iron, and thus produces the usual Heat; and by the effect of this continually augmented Heat, this solution being every moment more efficaciously carried on, of consequence the Mass grows hotter and hotter; so that at last, a Flame breaks out, partly from the Oil of the Sulphur which is freed from the Acid that is now gone into the Iron; and partly from the Vapour, that arises from the Iron now dissolved by the acid Oil of Sulphur, which is easily inflammable. That this is the Case appears from another beautiful Experiment mentioned in the place above cited, and in *Hoffman's Diff. Physi. Ch. 169*, which is as follows. Take a glass Bolt-head of a middling size, with the neck of it cut off, and mix in it 3 ounces of Oil of

Fire produced by mixing Iron, Sulphur, and Water.

Vitriol, with 12 ounces of Water; set the Glass then in a moderate Heat, and throw into it at different times, half an ounce or an ounce of Filings of Iron, and there will by this means arise a white Vapour, which issuing out of the neck of the Glass, causes a sulphureous stench like Garlick, and upon the application of a Candle, takes fire like Lightning, rushes with a vast *impetus* into the Glass, and being there violently agitated, produces very surprizing *Phænomena*; so that the Matter which constitutes these Fumes, seems perfectly like Alcohol, when it is raised by Fire into a Vapour. And thus there is discovered a new method of generating Fire in a cold Matter no ways inflammable, purely by the assistance of Water. And, indeed, we are most firmly persuaded, that there are in Nature, an infinite number of other methods, by which the same surprizing effect may be produced; and which possibly hereafter may come to light. Damp Hay laid together in a heap will do the same thing.

Of the Production of Fire by the mixture of cold Liquors.

Fulminating
Fire from
Liquids.

Take half a pound of very pure dry Nitre reduced to Powder, put it into a clean dry Retort, and mix with it an equal quantity of Oil of Vitriol very pure likewise, and perfectly freed from all its Phlegm: Distill this Mixture with a gentle sand Heat, continued for a considerable time, and then a Spirit will arise in form of a yellowish Vapour, which collected in the Receiver, will be *Glauber's* Spirit of Nitre. If in a glass Vessel, now, you put a Drachm of distill'd Oil of Cloves, Sassafras, Turpentine, or Carraways, and then pour upon it an equal quantity, or half as much again of this Spirit of Nitre of *Glauber*, a violent Flame will be excited by these Liquors, which were cold before the Mixture. Here again, then, is a most surprizing Experiment, and of infinite use in Chemistry, in which we see a most rapid Flame instantly produced by two cold Liquors, which almost consumes them both, leaving behind it only a small quantity of a kind of resinous Ashes. And by this Experiment, we perceive again likewise, that very acid Liquors mixed with oily ones, which are pregnant with a *Spiritus Rectior*, compose a matter very much resembling Sulphur, and that very easily takes fire. See *Borrich. Act. Hafn.* 167. *Hoffman. Obs. Phys. Chem.* 38, 42, 123, 127. *Slare. Phil. Transf.* N. 150. p. 291.

Of the nature of elementary Fire, which is corporeal. 1. As is extended.

If we examine now carefully what has been hitherto laid down, we may, possibly, be able to assert some things with sufficient certainty, concerning the nature of Fire. First, then, it is evident, that true elementary Fire is really corporeal. For as by this we mean something, that may be measured geometrically by three Lines drawn perpendicularly to one another from the same center, or, as we express ourselves now a-days, something extended; so, that Being, which we have considered in our former inquiries, under the notion of Fire, has appeared to be always extended. If, for instance, a solid silver Sphere almost red hot, is suspended by a Thread, and let very gently down into cold Water, so that it shall put the Water hardly at all in motion; will not the Fire then of this Sphere disperse itself gradually through the measurable spaces of this Water, of which that which is nearest the Sphere will be hottest, and the rest will be heated proportionably, and thus the Fire will be really extended? For Thermometers placed in the Water at different distances from the heating Sphere, will indicate the different degrees of Fire diffused through the Body and Spaces, and demonstrate a true Mixture of

of the Fire with the Body, or Space, and of consequence, a real extension of it. And, certainly, our whole History of Fire proves as evidently, that Fire is truly extended, as space is, or the Bodies contained in it.

A second general property that belongs to every known Body, is, that it may successively exist in the place which is next to that which it took up before, and thus may be really moved: And that, whether, first, it continues in the same space, but is turned upon its own *Axis*, and so all the parts considered together possess the same Space, though every particular part is changing its place every moment; or, secondly, the whole mass leaves the place it took up before, and enters upon a new one, and continues successively to do so; or, lastly, both these motions conspire together. But it appears, by every Experiment, that Fire is thus moved likewise; nor, indeed, was there one of them which did not demonstrate a true physical motion; and therefore this needs no farther proof. But this mobility, now, is so closely connected in Bodies with a power of being at rest, that no one can deny, but that that Body which one moment exists in any particular space, may be conceived to remain for two moments in the same; which is in reality being at rest: Since, therefore, all the actions of Fire, which are constantly performed by motion, may be always increased, or diminished; hence it is no ways absurd to suppose, that Fire may be absolutely at rest in a determined space; certainly not more so, than to suppose the same of any other Body.

2. As it is
movable, or
capable of
rest.

A third Affection of Body, and which is peculiar to that alone, is this, that a solid Body, as such, existing in any particular space, infinitely resists any other similar Body's possessing the same space, at the same time. To this some persons have given the name of Resistance and Impenetrability; *Democritus*, by a most expressive term, called it ἀντίστασις, or Repercussion. Nor indeed do I apprehend, we conceive any thing else by the word Impenetrability of Body, than this Repercussion of a Body, that endeavours to enter upon any part of space which was possessed by another before. But if this Repercussion, now, does really obtain in any Body, it does certainly in Fire in particular: For this puts in motion, and changes the figures of the very solidest Bodies we are acquainted with, so that there never was yet discovered any one that does not actually suffer some alteration from it in its true solid part, and receives a motion from it, by which it is carried into other parts of space with this *impetus* communicated to it by the Fire. But again, if we consider, that true, pure, elementary Fire, when it is directed upon certain Bodies, is driven back again, or reflected in such a manner, as to return from those Bodies, on which it fell, with a vast *impetus*, nay such a one as puts in motion every thing that is opposed to it; I say, if we rightly consider this, we certainly observe in Fire the most perfect ἀντίστασις; and by this means discover its real corporeal nature. For if, for instance, the igneous rays determined by the Sun, fall upon *Vilette's speculum*, when it is exceeding cold, and consequently, when it is most elastic, and reflects most powerfully, they will then be reflected into the *Focus* in a quantity that may be pretty nearly computed, with respect to the magnitude of the aperture of the *speculum*, and will there exert a most vehement corporeal force; which evidently demonstrates, that this Fire is moved with resistance. And this consideration confirms the argument still more strongly, that if the *speculum* is very much heated, and consequently dilated, looser, less elastic, and less powerful,

3. As it re-
sists Body.

with regard to its reflecting vertue, then the igneous rays, when they are returned back by it into the *Focus*, will act precisely with so much less force, as the hardness of the substance of the *speculum* was diminished. Hence, then, I think it appears certainly evident, that Fire itself is corporeal, and has a resisting power, inasmuch as it is reflected from the Body it strikes upon. But here again we observe, that if these igneous rays are vastly united together, and hence have their strength greatly increased, and become so powerful as to be able to melt the metalline substance of the *speculum*, then there will be no reflection produced, but the Fire being superiour to the *speculum*, will destroy it; a very evident proof, that this reflection arises from the mere repercussion of Body upon Body. But we may consider farther, that if this very pure elementary Fire is determined by the Sun through *Tschirnhausen's* Glasses upon the iron Needle of a Compass, it will then, in the very point where the *Focus* falls upon it, turn it round, and thus by a true corporeal percussion put in motion the substance of the Iron. This percussion now being made upon an impenetrable Body, demonstrates, that that, likewise, which moved against it, was not penetrable, but yielded some resistance. Elementary Fire, therefore, is truly corporeal. And every one of its elements or atoms, will consist of particles united together; which it is very probable are not capable of farther division by any natural powers. And hence the figures, likewise, proper to these elements, in all appearance, suffer no alterations by any force these powers are able to exert upon them. This wonderful element, therefore, is immutable itself, though it induces a change upon every thing else. But whether now Fire has likewise that property, which the great men of this age judge common to all Bodies, *viz.* that it gravitates in proportion to its solidity, does not yet appear so evident as persons generally imagine. For upon examination of the whole History of Fire, I am almost induced to believe, that it does not tend towards the center of the earth, more than any other point, but that it is perfectly free from any natural determination, or tendency to any particular place, or Body: That it may be determined every way, without resistance: That it exists in every place: That if there is no other cause to disturb it, it is dispersed throughout the whole universe: Nay, that naturally it exists every where, in the same quantity, and with the same power. All which positions, if I am not much mistaken, are plainly demonstrated by the former Experiments.

The Corpuscles of Fire the least of all we are acquainted with.

But in the second place, the elements of Fire, which by their first property appear to be corporeal, seem to be the least of all the Bodies that we are hitherto acquainted with. For if they are truly corporeal, they must, of consequence, be exceedingly subtil, since they are able to insinuate themselves with so much ease into the very densest Bodies, and passing through their whole thickness, exert their proper effects in the inmost penetrable parts of 'em. If a very large sphere of solid Gold, for instance, should be exposed to a proper Fire, for a sufficient time, it might be so penetrated by the Fire, as to be red hot to its very center: And if then it should be divided into two Hemispheres, there would appear Light, Heat, and every known property of Fire, in every point of their internal Surface. But again, the Subtlety of these particles is so exceeding great, that amongst all the Bodies that fall under our observation, there is not any one so compact, and free from pores, or of so large a size, but that it may be forced to transmit Fire through it. Every thing else,

of

of what kind soever, we can prevent entring into the *meatus's* of certain Bodies: Air, for instance, Water, Spirits, Salts, Oils, and all other Substances, we can exclude a Glass Bolthead, by hermetically sealing it, and by the same means include them so that they shall not possibly get out: Fire alone procures itself a free passage, both in and out, without any difficulty: Fire alone, both when it enters the Glass, and quits it again, exerts those effects which are proper and peculiar to it. I confess, indeed, that the causes of Gravity, and Magnetism, in like manner pervade all Bodies, without having their proper activity diminished: But then, whether these depend upon the emanations of Corpuscles, or act in some other way, that we are not acquainted with, is not yet so certain. Nay, and we must farther acknowledge, likewise, that both Gravity and Magnetism, in an instant, and almost without any retardation, penetrate through all Bodies, in their full force and efficacy; whilst Fire requires some length of time before it can pervade those that are very thick: But hence, certainly, the corporeal nature of Fire appears so much the more evident, which is not so manifest in the two former. For these reasons, therefore, I asserted only, that the elements of Fire are the smallest of all the Bodies that are universally acknowledged to be true Bodies. Far be it from me to deny, that the Divine Being has in the material World created Corpuscles that are actually more subtil than the Elements of Fire: This only I affirm, that it does not appear to the human senses, by any physical effect, that any such Corpuscles do really exist. But this infinite Subtlety of the Elements of Fire appears yet again, if we consider, that the Solidity of Gold is so great, that if you gild a piece of Silver with a grain of it, in such a manner, that the thickness of the golden foliage shall be only $\frac{1}{1050000}$ of a line (*Ac. Roy. des Sc. 1713. 10*), yet even then, when it is so vastly thin, you will not be able to discover the least pore in it, by the assistance of the nicest Microscope. Nay, if you take a bit of Leaf Gold, ever so fine, and oppose it to the Sun, shining through a hole into a dark room, it will not so much as freely transmit the Light, but you will see only a greenish kind of cast through it. And yet now a very large Sphere made of solid Gold, may be penetrated through its great bulk, and this prodigious density, by the smallest, as well as the greatest Fire. For if, in a very cold season, this great Sphere is exposed a considerable time to the cold Air; it will acquire the very same temperature, that is, it will receive the Fire that is at that time in the Air: But if it is then committed to a strong Fire, so that it may be perfectly red hot, and just ready to melt, it will then have a most intense Fire in every part of it; and yet if it is then in this condition removed into the Air, all this Fire will soon quit it again, and it will return to the common warmth of the Atmosphere. Hence, therefore, it evidently appears, that the small portion of Fire contained in liquid Air, can as easily insinuate itself into all the pores of Gold, as the most intense Fire of a Furnace. But if in such an exceeding fine leaf of Gold, now, the *meatus's* were so very small; what must we think of them in this case, when such a large Body of Gold is penetrated by Fire through all its Substance? Certainly, growing hot and cold, is nothing else but admitting Fire in a greater or less quantity. These arguments, then, sufficiently demonstrate the very great Subtlety of Fire. This, however, would appear yet infinitely greater, if this opinion was true, that the Matter of Light and Colours is the very same with that of Fire.

Fire. For if a chamber is perfectly darkened all but one very small hole, and an eye that has been some time in the dark, is placed directly against it, it will then see all the external objects very exactly, by means of certain distinct igneous Rays, arising, and propagated from every visible point of so many different Bodies, and transmitted through this very small aperture, without any confusion. If we consider, now, what an infinite number of visible points are seen in such a Hemisphere; and that every one of these appears only by its own particular Rays; the idea that arises hence of the subtlety of these particles confounds the human understanding. But again, if you place a Sheet of white Paper in this dark room, at a proper distance from the Hole, and by means of a convex Glass, throw the Rays upon it, then all the objects will appear upon this paper, of a pretty large size, and very distinctly; and consequently all these Rays, and therefore, upon our present supposition, all this Fire which from so many objects must be infinitely great, may be contracted together within the small space of this aperture. From these considerations, therefore, it evidently appears, that the Elements of Fire, with respect to our comprehension, are infinitely subtil.

And vastly
solid.

In the third place, these very small Corpuscles, the ultimate Elements of Fire, appear to be of such a nature, as to be the most solid, perhaps, of all Bodies. The signification of the term I make use of is easily understood: For by a Solid, I mean only that extended Being, which makes an infinite resistance; by Space, that Extension which admits and transmits Solids. An absolute Solid, therefore, is such an extended Being, where there is not the least such penetrable Space, but which through its whole Extension, and in every point of it, is perfectly impenetrable. If any Body, now, is composed of particles thus perfectly solid, but at the same time so united together, that there are left little spaces between them that contain nothing solid; then it appears evidently, that such an extended Bulk is partly Body, and partly Space. And it is hence evident, likewise, that the smallest Elements of all Bodies will be most solid; and that when these are afterwards compounded into one Mass, then, betwixt these Elements thus united together, but not touching one another in every point, there will be formed such Spaces within that Body. The compound Mass, therefore, will be always full of pores, and consequently less solid than the ultimate Elements of which it consists; and hence, in this respect, the parts may be more easily separated from one another, or are capable of a more easy division. But again, in these ultimate Elements, it is probable, that there are not any pores, and that hence they are perfectly solid, and consequently not to be divided by any other Bodies, but remain immutably the same. As Fire, therefore, has been demonstrated to consist of prodigious fine Corpuscles, if these have any pores, they must certainly be exceeding few, and consequently these *Molecularæ* will be vastly solid. But since impenetrable Substance is real corporeal substance itself, it is possible, that all true corporeal Substance, as such, may cohere with an infinite force not to be dissolved; but that the Masses that are made up of this Substance, with intercepted Vacuities, may be so far divisible as they contain these Pores within them. Fire, therefore, according to this doctrine, will be totally corporeal, immutable, incapable of having its figure changed, nor liable to any concretion with itself, or other Bodies. In the mean time, however, it will possess a
power

power of vastly dividing others; since it can always enter the Pores of the Bodies to be divided, exert its force there, separate the concreted Filaments and Particles, and thus resolve the Compounds into their simple Elements, or at least dispose the elementary *Moleculæ* in such a manner, that it may pass equably through the *Meatus's* in every direction; as we suppose may be the case in Gold, when it is put in fusion, which afterwards suffers very little alteration from the Fire. But if this vastly subtil and solid Fire, now, is applied to the perfectly solid Elements of other Bodies, it then seems probable, that it can induce no change in them, but only put them in motion by a mechanical propulsion, or by attraction; which again is confirmed by every kind of Experiment. Fire, therefore, in respect of this property, effects the most powerful changes in the Universe, whilst of all Bodies it remains itself the most immutable.

In the fourth place, we conceive, that these corporeal, exceeding small, and solid elements of Fire, have the most equably smooth, or polished Surface. And the
smootheft. By this we mean such a one, that has nothing in any one point of its circumference, which stands out, or is depress'd more than any other part. For if the Surface was rough, or unequal, then those points which were highest, would strike with a greater force against the Bodies they met with than any other part of the Mass; and consequently, in every action of Fire, either upon its own Elements, or other Bodies, those Particles would receive the greatest *impetus* which had the weakest cohesion with the whole Corpuscle; whence, it seems probable, that these Particles would be continually abraded from the rest of the Mass, and of course the Elements of Fire, and therefore Fire itself, would undergo perpetual Alterations; which is contrary to what has been already delivered: Besides, the vast solidity of Fire seems most consistent with that Figure, in which all the Particles are disposed in their several Orbs most equably with respect to their common center; since by this means they acquire the most immutable form, and most powerfully resist every transposition of their parts. But farther, if we consider with what ease Fire penetrates into the Pores of every kind of Body, let it be applied in what direction you will, then certainly, we shall see that the most smooth Surface is requisite that it may pass on without any impediment; which it does not at all seem likely would be the case, were it covered with little Hooks, Points, or any thing resembling Down or Wool. For since such a vast number of little Fires may be transmitted perfectly distinct through a very small hole into a dark Chamber, and that without the least difficulty; it is easy to conceive how vastly smooth the Surfaces of these Elements must be in the points of contact, not to intangle, and obstruct one another: And lastly, the exceeding quick reflection, and refraction, which are constantly observed in the Particles of Light, and which answer so exactly to the effects of a perfectly spherical Figure, induce us to believe, that the Elements of pure Fire do in reality possess this figure. Hence therefore, we may almost venture to infer, that the ultimate Particles of pure Fire are exceeding smooth polished little Spheres.

In the fifth place, from our whole History of Fire, we infer its exceeding great simplicity. And most
simple. By this we mean that condition of Bodies, where every single Particle is perfectly of the same nature with the whole: This, therefore, in Fire, would denote it to be of such a Nature, that every single Element of it,

it, should be a perfect corporeal Mass, without the least intercepted Pore, so that every component Particle should be absolutely alike; and hence, perhaps, be a little solid Sphere. And then if we consider a *congeries* of these Elements together, all these Spherules would be perfectly the same. In these, therefore, would consist the simplicity of Fire, depending particularly upon this circumstance, that as there are no Corpuscles in nature smaller than these of Fire, it is impossible it should be compounded of less, heterogeneous Particles. And certainly, the ultimate smallness, absolute solidity, and spherical figure of the Elements of Fire, very evidently denote this simplicity. Fire, therefore, we conceive to be the simplest of all Bodies. It must be acknowledged, however, that an absolute simplicity of Fire is repugnant to the doctrine of the great *Newton*, whose uncommon genius seems to have penetrated almost beyond the limits of human understanding. For this noble Author, by an artificial separation of one Ray of Fire, has divided it into seven different ones, not only perfectly distinct with regard to their Colours, but intirely different in respect of their Reflection and Refraction; and consequently, in these three properties, of a quite different nature. And yet, if we nicely contemplate such a Ray as this, how fine is it, and how simple? If the nature of Fire, and Light, now, has been examined by ingenious Men for so many ages, and with so much diligence, and the great *Newton* alone of our age has made these Discoveries; who will pretend to determine the farther Improvements that future ages may be able to make in Natural History? Who knows what additions may hereafter be made to the *Newtonian* Doctrine? Certainly, it is not above half a Century, since all the Philosophers imagined a single Ray of Light to be so infinitely fine, that they unanimously asserted, that with regard to its thickness it was indivisible: And yet that incomparable Geometrician, by undeniable Experiments and Arguments, has evidently demonstrated, that such a single Ray, is, in reality, a collection of seven Rays, which are perfectly distinct, and which, it appears, may be applied to one another through their whole length, and again be so separated from one another, as to be always capable of a longitudinal division into seven exceeding subtil Filaments, or Rays of seven different Colours. If, hereafter, now, this Science should be more subtly cultivated, and dioptrical Instruments should be carried to greater perfection, who will pretend to assert, that even in these simple *Newtonian* Rays, some penetrating genius may not be able to discover a still farther composition? These instances, in the mean time, are sufficient to raise our highest admiration, when we consider the noble faculties with which the Alwise Creator has endued the human mind, which being rightly employ'd, will conduct us to a discovery of those laws which were established for the formation of the Universe. And certainly, infinite reverence, and eternal thanks, are justly due to that gracious Being, who by impressing his own Image upon us, has made us capable of distinguishing truth, and disposed us to be delighted with it, and to use the utmost of our endeavours to attain it. But this, however, is not all the variety that has been observed in the most simple Particles of Fire; for even in such a single Ray, the same *Newton* has discovered another diversity in the nature of its opposite sides; as he found by accurately viewing the refraction in Island Chrystal, where he perceived the Ray to have a Power on one side, different from what it had on the other. And as in one Loadstone, with respect to another, the Pole is either attracting, or repelling; so likewise in one and the same Ray, there is a similar

lar Power with regard to its transparent substance. In Fire, therefore, tho' so exceeding simple, there is discovered a three-fold variety. 1. With respect to its seven different elementary Colours. 2. On account of the very different action of the Rays of different Colours, with regard to reflecting, and refracting Bodies. 3. In regard of the same diversity in the opposite sides of the same Rays, with respect to this Island Chrystal. In this so vastly simple Being, therefore, we see there still remains this manifold variety: What diversity, therefore, have we reason to expect in Compounds? In the smallest Bodies, we every where observe a resemblance of the greater. Had this discovery, which was reserved for the great *Newton* alone, still lain in obscurity, I don't doubt but we should all even at this time, have firmly believed, that in a Ray of Light there was somewhat ultimately small, and infinitely simple: But convinced by his Doctrine, we are now obliged to confess, that, tho' Fire is of all known Bodies the most simple, yet even in this, there is found to be a various multiplicity.

The sixth property of this Fire is its mobility, which is discovered to be so great, that we are almost certain, let it be where it will, it is never absolutely at rest. And here, I don't only mean that motion, which is constantly observed in all Bodies in general; for in this sense it is certain, that there is not one Body in the Universe, that ever for one moment enjoys a perfect quiet. The Sun, certainly, the Planets, and Comets, and their Atmospheres that gravitate with them, are all whirled about with very rapid motions: But these are the only Bodies that come under our observation. Nothing therefore is ever at rest, but the whole Universe is thus constantly kept in a swift rotation, as the Creator of all things has appointed it. But there is yet another motion which I ascribe to Fire, and which is the constant effect of its proper agility; and this is most evidently demonstrated by undeniable observations. Let us, for instance, consider Water, when it is 33 degrees cold, and it will then be in its coldest state, that is, it will contain as small a portion of Fire, as in the nature of things can possibly reside in pure Water; for if this simple Water is affected by a greater degree of Cold, it will not continue Water any longer, but will be converted into a Substance very much resembling Glass, in all the properties of hardness, brittleness, and pellucidity, tho' reducible again to Water by a Heat of 33 degrees, whereas Glass, to make it run like Water, requires a great deal more than six hundred. Hence, therefore, it appears evident, that Water is Water only by reason of the motion of the Fire residing in it, and that it is not Water from its own nature considered separately and alone. The same is true of Glass, Fossils, Sulphurs, Semi-metals, Metals, and perhaps, of all other Bodies; which appear in a consistent form in a smaller degree of Heat, as we observed just now in Ice, but are put in fusion, and converted into a kind of Water, if the same is increased to a certain degree, which will be different, according to the various natures of the Substance under examination. Since, therefore, by *Fahrenheit's* Thermometers, the natural Heat has been observed 32 degrees below the freezing point, hence, we see evidently, that through all this difference of 32 degrees, the Fire was agitated with a motion, that grew gradually less, and less, but was never totally destroy'd; and therefore, even at that time, when all Animals and Vegetables perished through the excess of the cold, the Fire was not absolutely at rest. We may safely assert, therefore, that the Fire was even then in motion. But, as it has appear-

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ed since by the same Experiment, that this Fire may be artificially diminished still 40 degrees more; hence we are now certain, that Fire in the greatest possible natural Cold, is agitated 40 degrees more than it is in this artificial one, and that again through every intermediate degree, it is continually dissolving some Bodies, which a little after, in a smaller degree of Heat, appear of a solid consistence: These things the Experiments referr'd to abundantly demonstrate. Fire, therefore, is perpetually agitated in the greatest Cold, and still gradually more and more in every increase of Heat; and hence it is always in motion. The famous *Romer*, from a great number of certain astronomical Observations carried on for the space of ten years, very ingeniously inferred the vast swiftness of the Fire derived from the Sun to the *Satellites* of *Jupiter*, and thence reflected to our Earth; for from these *data* Mr. *Hugens*, to whom this was communicated by *Romer*, evidently demonstrates, that the propagation of it is so swift, that it moves more than 1,100,000,000 feet, in the space of a Second. See *Hugens, de Lum.* p. 8, 9. This velocity, therefore, of Fire, or Light propagated from the Sun, which is looked upon to be true elementary Fire, would be vastly great, if we suppose it to proceed from the Sun, and fall upon the *Satellites* of *Jupiter*, and to be thence derived to our Earth, which seems agreeable to the *Newtonian* Doctrine. And if we suppose, as others will have it, that these Spaces are perfectly full, yet still, the action of luminous Fire, be it what it will, must be communicated with the same celerity. Afterwards, however, the great *Cassini*, and *Maraldus*, Men of infinite industry, and perfect Masters of Astronomy, carefully examined this affair by the most accurate Observations of a great many years, and discovered, that the opinion of Messieurs *Romer* and *Hugens* was very far from the truth. *Mem. de l'Ac. Roy.* 1707. *Hist.* p. 77. *ibid.* *Mem.* p. 25. On this account, therefore, we don't pretend to determine any thing farther concerning the celerity of Light from these very subtle disputations: This, however, we are certain of, that the communication of it will be always so much the swifter, as it is found to be less successive.

Do not generate Fire.

Or are generated by any other means.

In the seventh place, from what has been laid down, we may certainly conclude, that tho' this elementary Fire induces an infinite number of changes upon all other Bodies, yet, it never has appeared by any Experiment, that any of them have ever been converted by it into true elementary Fire. And hence, it is not confirmed by any Observation, that Fire is able to multiply itself, by changing its own *Pabulum*, or any Bodies into true Fire, by assimilating them to its own nature. Certainly, the more carefully we consider all the effects of true Fire, the less conclusive those Arguments appear, which are brought to prove such a power in Fire, or such an aptitude in other Bodies to this transmutation. Hence, therefore, it will be evidently certain, that if Fire itself cannot from any other Matter generate Fire, it cannot possibly be generated by any other Matter. For what cause can by any action produce Fire from a Body that is not Fire, if this cannot be effected by Fire itself? In the whole compass of Nature, certainly, we discover nothing, that, with regard to such a Power, can any ways be compared with it. This seems to be the grand universal Mover, from which every thing else receives its motion, all Fluids at least, and perhaps a great number of Solids; which is itself never begotten *de novo*, renewed, or resuscitated, but is only rendered discernible where it did not appear before.

Since,

Since, therefore, we are undoubtedly sure of these things, we may now freely assert, that this elementary Fire is always, and every where the same in every Body that is heated by Fire, whatever way it is excited, whatever *Pabulum* it is fed with, or by what contrivance soever it is supported. Unjustly therefore do the Chemists complain, that in their most subtle Operations, they cannot have the advantage of pure Fire; for in these, they imagine the most pure, astral, celestial, solar, elementary, incorruptible Fire, to be intirely necessary. But had they rightly considered what has been already laid down, they would never have embarrassed themselves with this needless solicitude: For the Heat that is generated in the Bodies of Animals, Vegetables, and Fossils, owes its Being intirely to the very same Fire; and when it passes through a glass Vessel into its cavity, is as pure, as if the Vessel had been exposed to the most lucid Rays of the brightest Sun. The Heat of burning Alcohol too, and fossil Coals, when it acts upon any Matter included in a clean glass Vessel hermetically sealed, if it is reduced to the same degree with that of the Sun, and is applied in the same manner, will appear perfectly the same by every effect. Nay, I add farther, that the Fire which is generated by the fetid putrefaction of the most putrid Bodies, when it has pass'd through dense Glass, is as pure, simple, and sincere, as if it had been propagated thither by the clearest Sun. The Heat, therefore, generated by putrefaction, fermentation, and the putrifying Dung of Animals, is the very same as that from pure Fire. And hence, I see no difference betwixt the Heat of Horse Dung for chemical Operations, and any other whatsoever, that is of the same degree, and is applied in the same manner. In Nature, therefore, we meet but with one sort of Fire; for both the elementary, and artificial, are always the same.

What I have here said, however, must not be understood of common Fires; for in these all sorts of Bodies float about with the pure Fire, and being mixed with it, according to their different Natures, and the alteration induced upon them by the Fire, affect the Bodies exposed openly to them in a very different manner from what they would have been affected, had they been acted upon by a solar catoptrical, or dioptrical *Focus*: Nay, and very differently too, with respect to their own proper Nature. But then, in this case, this various action of Fire does not depend upon Fire, as Fire, but upon Fire, and the other Corpuscles, that at the same time are agitated with it, which certainly makes a vast deal of difference, falsely ascribed to a diversity in Fire itself, which in reality appears to be always the same. The effect, however, of this Fire upon other Bodies, is very different, whilst it is supported in the manner above explained, by various sorts of Fuel; for by this means it acts with more or less violence, and even mixes with them the Particles of its *Pabulum*, which is agitated, vibrated, and often united with it.

In this respect, therefore, the Fire that is excited and supported by burning Alcohol, is the purest of all, and least of all affects the Bodies exposed to it with any impurities from the combustible Particles.

The next pure to this, is that which is fed with Oil often distilled, especially from a fixed alkaline Salt, and hence rendered exceeding fine, simple, subtil, and limpid, like Alcohol. Under this head come the native *Naptha* and *Petroleum*, which are endued with the same property.

Next to this follows the Fire of well prepared Charcoal. Then that of

Nor have
any diver-
sity.

The Fire of
common
Fires the
same, but
mix'd with
other Bodies.

With Alco-
hol.

With the
purest Oils.

With Char-
coal, Wood,
Turfs,

pure Wood ; which is succeeded in purity by that from Bituminous Turfs. And these are of two sorts, the one found in Heaths, where the upper Surface being pared off, affords a pure Fuel ; the other which is made from a wet, black, fat Mud, which being dug out of proper Pits, and then dried in the Sun, is divided into Parallelipeds: These yield a noble, wholesome, steady Fire, which the illustrious *Boyle* was formerly so mightily pleased with.

With Coal
made from
Turf,

When this Turf is burnt 'till it is perfectly red hot quite through, and no longer emits any visible Smoke, if you then extinguish it, it affords a Coal, which when it is dry, takes fire with a vast deal of ease, and is exceeding fit for a great many purposes ; for it produces no Smoke or disagreeable Smell, continues to burn a long while of itself when once it is kindled, and yields the most equable Fire of any thing we know of.

With Fossil-
Coal,

To these more compound Fuels belong likewise the Fossil Coals, which consist of an Oil like the Fossil Oil of *Naptha* or *Petroleum*, and another Matter that will vitrify.

And Dung.

And lastly, the dry'd Dung of some sorts of Animals. The vast variety therefore that is observed to happen so often from the action of Fire in its physical effects, must be ascribed intirely to the different nature of the *Pabulum* it is fed with: This may be confirmed by abundance of Examples, but one or two will make it sufficiently evident. Wood, for instance, or Turf, when they burn in the open Air, emit a Smoke that is not very pernicious, only making the Eyes smart, and affecting the Lungs in such a manner as to provoke a Cough ; and yet, if you convert either of these into Coal in the manner above-mentioned, and then dry it thoroughly, and set it on fire and let it burn 'till it is perfectly red hot, there will arise from these Coals a very fine invisible Fume, which in a close place is very quickly fatal to all sorts of Animals. And in this affair there is something very remarkable ; for it appears by Experiment, that if you take an Animal, and put it under a large Glass, and draw some of the Air out, but not so much but that the Animal might live in it for some time ; then, if by the help of a Pipe you convey the external Air into the Glass, in such a manner as to make it pass through smoaking Coals, it will not destroy the Animal ; and yet if the same passes through Coals that are perfectly red quite through, it will be instantly suffocated. And very often too, there is some very extraordinary power communicated to Fire by the Air, as we see evidently in an Experiment related by that famous Writer of *America, á Costa*. For he tells us, that the native Silver that is dug out of the richest Mines of *Peru*, cannot, so long as it adheres to its Ore, be melted by the strongest Fire that can be raised by the largest Bellows ; and yet if this Fire is blown up by an artificial Wind procured by the fall of cold Water, and convey'd, and forcibly directed upon it by proper Instruments, the fusion of the Silver is soon obtain'd without any difficulty: These, therefore, and many other instances, sufficiently point out to us, how very circumspect we ought to be, if we would rightly understand the action of Fire upon other Bodies, since the minutest circumstances very often make a great deal of difference with regard to the event. There are a few things in our History of Fire still remaining to be considered, which will hereafter be of very great service in our chemical inquiries.

In the first place then, don't let us be led away by that vulgar opinion, that Fire is a universal solvent of all Bodies: That it dissolves a great many, indeed, we readily allow; but at the same time we must deny, that it has this effect upon all. Nay, upon the very same object, in different degrees of it, we see it acts in a quite different manner. If you put some Mercury, for instance, into a Bolthead, and apply a gentle Fire to it at first, and afterwards gradually increase it, it will, in length of time, be converted into a various-colour'd Powder, something of a fixed nature, and scarcely miscible with any Liquor; and yet, if you apply as strong a Fire to it at first, as you did at last, it will all immediately evaporate. And farther, if the Mercury thus fixed by a gentle, and gradually increased Heat, is at once exposed to a strong Fire, it will again become totally volatile; so that we see plainly, what the Fire effects in one degree, it destroys in another.

Fire is not a
universal
Solvent,

In the second place, Fire is not so pure a dissolvent, as to extract from Bodies only those parts that existed in them before; for at the very same time that it separates some parts, it mixes others together. Nothing can be more evident than this in many instances. Antimony, if it is exposed to a strong dioptrical, or catoptrical *Focus*, emits a vast quantity of Fumes, and yet, at the same time, has so large a number of other Corpuscles united and fixed with its *Calx*, that it considerably increases in its bulk. If Lead, by the same method, is converted into *Minium*, there rises likewise from this abundance of noxious Vapours, and yet the *Calx* acquires a considerable addition to its weight. In Corals too, calcined by a strong and long continued Fire, their weight is in the same manner augmented. And lastly, if Mercury, that is by a particular Art purified by the help of Metals, is digested for a long time in a glass Bolthead, it will be converted into a fixed Powder, and a very small portion of good Metal, with an increase of its original weight.

Nor divides
Bodies into
their real
constituent
Parts,

Thirdly, from some sorts of Bodies it produces nothing new, but leaves them without any considerable alteration. Gold, for instance, Silver, *Osteocolla*, *Glass*, the *Selenitis*, *Talc*, and *Virgin Sand*, are not separated, either into their Elements, or other Substances, by the simple application of Fire. Consult *Van Helmont* in various places, and *Boyle* in his *Sceptical Chemist*, from p. 10. to 33.

Nor effica-
ciously dis-
solves all
Bodies.

In the fourth place, there are every where to be met with, great numbers of Bodies, from which it is impossible, by the help of Fire alone, apply it in what manner you will, to separate different Substances, though we certainly know, that Bodies of quite different natures enter into their composition; nay, and can readily, by the assistance of other Instruments, resolve them into their constituent Parts. A great many such Bodies we find taken notice of among the learned; our present Subject leads us to mention a few of them. Gold, Silver, and Copper being melted together, and thus intermixed with one another, produce a Mass, from which the power of Fire will not easily separate again these three simple Metals. If, with twenty times the quantity of good Lead, you manage this Mixture according to Art, in an Assaying Furnace, you will soon very accurately separate the Copper, and there will remain a pure Mass of Gold and Silver. Apply, now, to this whatsoever Fire you please, the Silver will constantly remain united with the Gold; nay, and in such a manner, that the very least Particle of this Mixture will always contain the same Proportion of Gold and Silver, as was in the whole piece. But if you then throw this Mass into

Tho' they
are separable
by other
means.

pure

pure Spirit of Nitre, the Spirit will intirely dissolve every Particle of the Silver without the least remainder, and the Gold will lie at the bottom of the Vessel, in form of a black Powder. The Silver, then, which is thus separated from the Gold, and resides in the Spirit of Nitre, you will not be able to separate again totally from the Spirit, without a good deal of difficulty; for if you call in Fire to your assistance, the Mass will, by the application of this, at last grow dry, and become the *Lapis infernalis*, in which the Acid of the Nitre very tenaciously adheres to the Silver, and runs with it in the Fire without any Fumes, in the same manner as if it was one simple melted Metal; but now, if into this Solution of Silver by the Spirit of Nitre, you immerse some thin Plates of Copper, then the whole Substance of the Silver, without any remainder, will be disengaged from the Spirit of Nitre, and every thing else, and lightly adhere to the copper, from which being shook off to the bottom of the Vessel, and then washed with Water, you will obtain your Silver again, in the greatest purity: So that here we see, likewise, what the Power of Fire was not able to effect, is brought about by some other means. It's needless to make mention of the Sulphurs that are mixed among the metalline Glebes, which adhere to them in such a manner, that they either keep melted with them in the Fire, or else carry 'em off with them into the Air. How unsuccessful, and with what disadvantage, have the Metallurgists endeavoured, by the help of Fire, to dissipate the volatile Sulphur, that the Metal might remain pure at the bottom of the Cupel? And yet if with these you mix some fixed alcalious Salt, or Iron, which in the Fire greedily unites with Sulphur, or any absorbent Powders made of these or the like materials, as soon as ever the Sulphur has absorbed these additional Substances, and united them with itself, it produces some sulphureous *Scoriae*, and gives you the pure metalline Glebe at the bottom. Examine Antimony, and whenever it is pure, it appears to be homogeneous. Manage it by Fire, in what manner you please, and it will either be intirely carried up in Fumes, or, if the Fire is gentle, will totally remain in it. But if you mix with it, now, Tartar and Nitre, or Iron and Nitre, and then set it on fire, the external, sulphureous Part will be immediately separated, and the metalline Mass will be left behind, intire, ponderous, and homogeneous. If you put the same Antimony into *Aqua Regia*, the Sulphur will be cast out unaffected by the Acid, whilst the *Aqua Regia* siezes upon the metalline part, and unites it with itself. *Sal-Ammoniac*, which is truly a compound Substance, in a greater degree of Heat, rises totally, and without separation; in a less too, continues undivided; and yet, by an addition of a fixed alkaline Salt, it is very readily resolved into a fixed Sea Salt, and a volatile animal one. *Mercurius Sublimatus Corrosivus*, if it is for a long time exposed to the Fire, continues compounded of the acid Spirit of Salt, and Mercury; but is freed from its Acid by mixing with it Iron or *Alkali's*. Chemistry every where furnishes us with numberless Instances of the same kind.

Not divides
them into
simple Ele-
ments.

In the fifth place, it deserves our notice, that those parts, which are separated by Fire from compound Bodies, how carefully soever you apply it, are not in reality simple Substances, but are variously intermixed with one another. If you examine, for instance, the simple Waters, that are drawn by Fire, does not the odour at first drawing, and the Turbidity, putrid Smell, and slimyness they naturally acquire in keeping, make it evident, how much they are still compounded, since none of these things are ever observed in pure Water? Consider the
Spirits,

Spirits, and you will find that they consist of a Water and Salt, so intimately united together, that it is not possible to separate them by any Art, except by the joint assistance of fixed Salts and Fire. But what shall we say of the Oils? The common Chemists look upon these, as most simple, pure, sulphureous Elements; but the top masters in the Art make it evident, that these too are remarkably compounded of various Substances. For in these there is that inflammable Element, of which we have so particularly treated above, a great deal of Water, and some quantity both of Salt and Earth, intimately united together. And lastly, as for the Earth that is extracted by Fire from compounded Bodies, what a vast deal of trouble is required before it can be obtained perfectly pure? Certainly it is always tenacious of some fixed Salts, even till it begins to be converted into Glass.

In the sixth place, it appears by abundance of Experiments, that the composition of Bodies is as much affected by the action of Fire as their separation; for it unites the most different Bodies so intimately together, that the new formed Substance appears perfectly simple, and is not liable to any alteration from its power afterwards. For Sand, we know, by being calcined, melted, and intimately mixed with a fixed Alkali, by the force of an intense Fire, produces Glass, which is then so simple in the whole, and every part, that we scarce know any thing more so, or harder to be dissolved, since it can be separated into its simple parts by no other means, than by melting it with a great quantity of fixed Salt, that it may become of a saline nature, and then pouring an Acid upon it, by which means an exceeding subtil powder of Sand will be precipitated from it. The various kinds of Soap demonstrate the same thing. The distillations of *Aq. Regia* evidently confirm it likewise; as well as the artificial mixing of Metals. But what need is there of more instances? Does not universal nature make use of Fire, as its principal instrument in the production of its compound Bodies? What Compound is generated, either in the animal, vegetable, or fossil Kingdom, that does not owe its origin to a soft, digesting, disposing, compounding Fire? Certainly, the gentle and steady action of that grand mover, Fire, seems to be the principal cause that every where brings about the most strict and intimate union; nay, even so much, that it may be doubted, whether Fire is most efficacious in the composition of Bodies, or in their dissolution. Without dispute, it hath a vast effect in both.

In the seventh place, it ought particularly to be taken notice of, that the very same Fire, if it is applied in different degrees, will in one, compound those Bodies, which it will again resolve in another. This the Chemists have frequently learned to their cost, for when they have spent years in fixing Mercury by a gentle Heat, successively increased through various degrees, and by this means have obtained a red powder, which remained a good while fixed in the Fire, they have found that at last, when the Fire was rendered intense by the assistance of Bellows, it has been dissipated into the Air; and thus being disappointed of their expectations, have experienced, that Fire separates in one degree, what it before united in another.

But eighthly, the very same degree of Fire applied to the same Bodies in different circumstances, produces effects that are surprizingly different, and that particularly, according to the various admission of the Air in the operation. The famous *Hook* took a Coal, and by means of a Cover that screwed on, perfectly

Nay, and it compounds Bodies.

And again, separates the Compounds.

Acts variously, with regard to the Air.

perfectly inclosed it in an iron box. In this manner he exposed it to a very strong Fire, for a considerable time, and yet when he took it out, the Coal, by such a violent action of the Fire, was not burnt up. See *his Life in his Posthumous Works*, p. 21. Hence this ingenious Philosopher inferr'd, that the Air is a *menstruum*, which, being agitated by Fire, will dissolve all sulphureous Bodies, since Fire, without the assistance of the Air, is not able to effect it. The same thing *Van Helmont*, in his Distillations, had formerly observed in his fixed Coal. And *Rapin*, *Receuil des Machines*, p. 25, 26. And when, before you here, I put some Shavings of *Guaiacum* into a Retort, and urged them with a very strong Fire for a long while together, there remained at last, as I told you, some black *Fæces*, that still retained an Oil, which the utmost force of the Fire was not able to force out of the Retort. But when this powdered Coal was laid in a large Dish, and examined, by dropping a spark of Fire into it, then the black Oil was immediately consumed with an aromattick Smoke, that smelled like Cedar, and the Shavings were turned into insipid white Ashes. Camphire, if it is set on fire in the Air, will intirely consume, though it swims in Water; and yet if you expose it to the Fire in a clean glass vessel, with an Alembic over it, it will melt and rise into the Alembic, and there harden into the same Camphire again without any alteration. And though you repeat this a good many times, the event will be still the same. May not Sulphur be sublimed a hundred times in a close Vessel, and still remain the same Sulphur? And yet if during the sublimation, there happens to be a crack any where, so that the Air can have a communication with the melted Sulphur, it immediately takes fire, and is instantly resolved into a blue Flame and an acid Fume. Amber, if you set it on fire in the open Air, almost totally burns away, and supports Flame and Fire; but if you urge it in a Retort with the strongest degree of Fire, but gradually increased, you will force into the Receiver a Water, Spirit, a volatile acid Salt, an Oil of various sorts, and with the last degree will make the whole substance of the Amber come over the neck of the Retort; as I have frequently myself experienced. Fire, therefore, when it acts upon inflammable substances, without Air, or with Air that stagnates, and is without motion, produces very different effects from what it does in other circumstances.

And various-
ly in various
degrees.

Ninthly, and lastly, the same Fire applied to the very same Object, but in different degrees, is very various in its Operation; as appears, likewise, by Experiments. Take, for instance, the fresh White of an Egg, put it into a clean Vessel, to which there is a free admission of the Air, and let it be exposed to 92 degrees of Heat, in *Fahrenbeit's* Thermometer, and it will in a little time be resolved into a Liquid, that grows continually thinner and thinner, becomes sanious, fetid, and putrid, and at last runs just like Water, nor will be coagulated by the Heat that makes Water boil; and thus it is converted into a most putrid, volatile Alkali: But now, if the same White of Egg is exposed to 200 degrees of Heat, in the same Thermometer, it is immediately changed into a white, solid, scissile, insipid Mass, exhales a large quantity of inodorous, insipid Water, and at last there remains at the bottom an exceeding hard, brittle, pellucid, insipid, inodorous Substance, that may be kept for years without any alteration: And again, the same White being urged by a Fire of 400 degrees, in a glass Retort, yields a Phlegm, Spirits, fetid

fetid Oils, an oily, fetid, alkaline, volatile Salt, and an exceeding black Coal that is surprizingly puffed up by the Fire. But there would be no end, Gentlemen, should I go about fully to explain the nature of the power of Fire. Let it suffice at present, that I refresh your memories with a short abstract of this Doctrine, as it has been already delivered, *viz.* that the action of Fire, as it may be varied under all the circumstances above mentioned, is capable, as a concurring cause, of producing the greatest part of the physical effects that fall under our observation. It can alter Concretes in their Figures, and Cohesions; but in such a manner, however, that a difference in the Concretes produces a variety, with regard to this power; for Fire is never able to produce the same thing from different Bodies, but some certain things from particular ones; and then, besides, there will be yet a farther difference, according to the various order, degrees, and application.

Our Dissertation of Fire, Gentlemen, is thus then at length so far advanced, that we are now able to treat of that knowledge of Fire, considered as present, and operating in a particular place, which an Artist ought to be acquainted with, in order to know how to direct and keep up such a Fire, in a given place, as is proper for the inducing such and such changes in certain Bodies. This doctrine was laid down by the ancient Chemists, and is at present almost brought to its greatest perfection by means of those beautiful Thermometers of the ingenious *Fahrenheit*. It was their opinion, that the power of Fire might be conveniently enough reduced to four degrees, and that this distinction was sufficient for the exercise of their Art: Of this matter, however, they gave us but a very obscure Account: Nor have the moderns made any considerable additions. Let us, therefore, Gentlemen, undertake this point, and call in Art to our assistance, but Art that is formed upon Nature.

Of distinguishing and managing Fire.

The first degree, then, of Chemical Fire, I call that, within the compass of which Nature brings about the work of Vegetation in Plants, and by which the Chemical Art imitates the same. This begins from the greatest degree of Cold, *viz.* Number 1. in *Fahrenheit's* Thermometer, and ends at the degree 80: For through all the degrees contained betwixt these limits, Vegetables of one kind or other give plain indications of Life and Vigour. Don't you, in the most piercing cold, see the bitter mosses growing upon the barks of Trees, and indeed scarcely at any other time? Don't the Fir, the Juniper, the oriental Larch-tree, the Cedar, the Pine, the Savine, the Yew, and the *Arbor vitæ*, retain their verdure in the sharpest Winter? Not to mention the Sea Mosses, the Land Mosses, the Black Hellebore, the *Hepatica Nobilis*, the Snow-drop, the Winter Wolf-bane, the Bastard Hellebore, and others; which in the hardest Winters put out Leaves, flower, generate, conceive, and bring forth, notwithstanding the check one would imagine they should receive from the intenseness of the Cold. In short, if you carefully examine all the Plants that we are at present acquainted with, by the degrees of Heat contained within the bounds here described, you will find some Plant or other that comes to its maturity in almost every one of these intermediate degrees.

The first degree of Chemical Fire.

Hence it appears very probable, that the Chemist, by a well managed degree of Heat, may in his artificial Stoves imitate that power of Fire, which Nature makes use of in the generating of Vegetables, so as by gentle degrees to

The remarkable use of this.

proceed to cherish the Plants, and not to destroy them. If you desire to excite such a Heat as this, upon a proper furnace place a vessel full of Water, in which dispose a Thermometer, and then you may, by increasing or lessening the Fire, easily reduce the Water to that temperature which is for your purpose. When the Water is thus found to be sufficiently warm, put the Body you would make the Experiment upon in a glass Vessel, and set it in the Water, which by this means will communicate to it a proper degree of Heat. Is it not very probable now, Gentlemen, that this degree of Heat is the best suited to impregnate Oils with the choice Spirit of some Vegetables, without dissipating the most precious Part? If one wanted, for instance, to impregnate an Oil with the most fragrant Spirit of Roses, what method is more likely to succeed, than the taking some Roses, gathered in the morning, and digesting them with some pure, inodorous, and almost insipid Oil of Olives, in a tall Bolthead, in 56 degrees of Heat? Such a Heat certainly will so unite and intangle the Spirit of the Roses in the viscosity of the Oil, that it will not be easily disengaged again, but will produce a most fragrant Balsam. And if you would enrich the most liquid Alcohol with the choicest Spirit of Saffron, make use of the very same degree; for with a less you will scarcely extract it from the Substance of the Saffron; with a greater, you will dissipate those particles which are most volatile. There are but few who have a right notion of this Affair; those, however, who are best acquainted with these things, know it to be true. By this caution in the management of the Fire, it is certain, there are incomparable Medicines prepared, which become good for nothing, if you increase it beyond its proper bounds.

The second
degree.

The second degree of Fire may, I think, be most conveniently measured by the Heat that is at some time or other observed in healthy Bodies. This, in its lowest State, is supposed to begin at the 40th degree, in *Fahrenheit's* Thermometer, and in its greatest height, to rise to about 94. Within this compass Animals seem to be capable of subsisting, if their humours have any degree of Heat in them, that is contained between these Limits. There are some kinds of Insects that live with a very small degree of Heat in their vital Juices, and nothing seems to me more surprizing, than that the *Embryo's* in the Eggs of Caterpillars (which they lodge, when they are impregnated, in a viscid matter circularly disposed round small twigs) should remain secure in their little Nests, during all the severe Winter of the Year 1709, and the very sharp one of the present 1729: For notwithstanding every body would be ready to imagine, that they must have perished through the extremity of the Frost, yet by the kindly influence of the warmth of the approaching Spring, we saw the Worms able to disengage themselves from their Eggs, and thus make it appear, that they had stood out against the great severity of the weather. Fishes too, belonging both to Seas and Rivers, that have Gills instead of Lungs, live and keep moving continually in Water that is 34 degrees warm; and if the Heat of it is increased from hence as far as 60 degrees, and better, they are still in some measure able to bear it. But Fishes that are furnished with Lungs, like other respiring Animals, in the time of health, communicate to their humours a warmth of 92 degrees, a little more or less; and hence they will subsist in any degree, betwixt 33 and 94. Within the compass of this Heat are included the vital actions of Animals, the fermentation of Vegetables, and the putrefaction both of

The use of
this.

of Vegetables and Animals; as likewise the generation, breeding, hatching, birth, and nutrition of Animals. This degree of Heat the most experienced Chemists make use of to prepare their Elixirs, volatile alkaline Salts, both simple and oily, and their Tinctures; and employ the same in concocting their Mercury to the first preparation of the Philosopher's Stone.

The third degree of Heat begins at the degree 94, and reaches as far as 212, The third degree. in which Water generally begins to boil. Through this whole intermediate space, the Water and native Spirits are separated from all kinds of Animals and Vegetables; and the *Residuum* grows dry, becomes durable, and almost immutable. The essential Oils of Plants in this Heat become volatile. The Salts and Oils, in the fresh Juices of Animals, are scarcely raised, but the Juices are dried into a thick, hard, brittle, insipid, inodorous Substance, which will keep for years without any considerable alteration. And hence it appears, with how little reason some persons imagine, that volatile, alkaline, oily Salts, are generated and retained in a healthy Body. This degree of Heat serves for the distillation of the distilled Oils, and medicinal Waters of Vegetables. The sanguineous ferous Juices of Animals coagulate in boiling Water into a Mass that will bear to be cut asunder; whilst all their Solids are destroyed by it, and reduced to a thick, tenacious Liquid. And hence it is absolutely destructive to all Animals. The efficacy of this degree.

The fourth degree may be reckoned from the degree 212 to 600; within which limits, all Oils, Saline *Lixivia*, Mercury, and Oil of Vitriol, recede from the Fire, are carried upwards, and by this means distilled. In this too, Lead and Tin are put in fusion, and may be mixed together. The Oils, Salts, and saponaceous Juices of Animals and Vegetables are rendered volatile and acrid, and become more or less alcalescent: The solid parts of them are dried, and if they are calcined, are changed into a very black Coal, are all absolutely destroyed, quite altered in their qualities, and lose intirely their proper Virtues. Within this Heat too are sublimed Fossil Sulphur, and *Sal-Ammoniac*. The fourth degree.

The fifth degree of Fire may contain that latitude, in which the rest of the Metals are put in fusion. This will begin at the degree 600, and reach as far as that which is capable of melting Iron. This degree, Glass, Gold, Silver, Copper and Iron, bear a considerable time, whilst it destroys every thing else. In this degree all other fixed Bodies grow white with Heat, the fixed Salts of Vegetables and Fossils are put in fusion, are deprived of almost all their Oils, acquire a greater and greater alcalious acrimony, and with Sand or Flints are converted into Glass; Lime-stones are calcined; all other things either vitrify, or become volatile, and are dissipated into the Air. The fifth degree.

The sixth and last degree comprehends the whole compass of the dioptrical and catoptrical Fire above describ'd; which hardly any Body is able to resist: By this even Gold itself suffers very surprizing alterations. Concerning this Fire, consult the Observations of *Mess. Homberg, Hartsocker, and Vilette*, and what we formerly delivered upon this Subject. The principal effect that this Fire commonly has upon almost all Bodies, is the turning them to Glass. The ultimate effect, therefore, of the Fire that we are at present acquainted with upon fixed Bodies, is their Vitrification. This the most ancient *Magi* of the East seem to have understood, when they prophesied, that the whole World would at length be destroyed by Fire, and that it would then be converted

verted into pellucid Glass. Thus far, then, at least, our doctrine of the degrees of Fire stands upon a sure Foundation; as for the ultimate power of it, the human mind will never be able to fix its limits.

A certain direction for these degrees.

In the next place, now, it is of great consequence for us to be acquainted by what means we may know how to raise and keep up a Fire to any degree that we have occasion for; on this principally depends all the operations of the whole art of Chemistry.

First, the nature of the *Pabulum*.

And here it is much more difficult to preserve a great degree of Cold, for a considerable time, than it is to keep up a very great Heat; as the metal and Glass Works, where such intense Fires are requisite, most evidently demonstrate. The first way, then, by which we may keep a Fire moderate, is by choosing such kind of *Pabulum*, afore described, as is proper to produce such a strength of Fire as is fit for our purpose. Alcohol of Wine yields a weak, and equable Flame, that may be easily increased or diminished by a greater or less number of wicks. When you are determin'd, therefore, about the degree of Heat, that you design to make use of, it is a very easy matter to light a Lamp with so many Wicks as appear by the Thermometer to be necessary to excite the degree desired. After Alcohol, follow the lighter, porous, spongy kinds of *Pabulum*, as Rushes, Straw, dry Leaves, Hair, Feathers, Shavings, dried Stalks of Buck-wheat, Chaff, and Bran. Next in order, Oils, Tallow, Wax, Camphire, Pitch, Rosin, Sulphur, and other Compounds. Then thick, heavy, hard, sound Wood, not too dry, and the Coals that are made from it. And, lastly, red hot Metals; and fossil Coals.

Secondly, the quantity.

Again, various degrees of Fire, even to the greatest, may be raised by the quantity of combustible matter thrown on; for if a vast quantity of Fuel is set on fire all at once, then the Fire that is produced by it will be always proportionably stronger, the force of it all being united together.

Thirdly, the distance.

But farther, there will be a vast deal of difference in the Heat, with respect to the Object it acts upon, according to the distances in which the Body is exposed to the Fire, the Heat always decreasing, as it is removed farther off. A great many famous Philosophers have been of opinion, that this difference might be determined by one simple rule, *viz.* that the forces of corporeal qualities always decrease in a reciprocal proportion of the squares of the distances from the center that generates these qualities; and hence that Fire too acting at double distance, has only one fourth part of the force. But before we can be certain of the truth of this, we must first be sure, that the Fire itself, when it is contracted into a narrower compass, does not acquire some new power, not depending upon the number of the Elements alone, but upon some efficacy which they acquire by being brought nearer to one another. And indeed, if we carefully examine this Affair, we shall find, that though it is true, indeed, that the farther we recede from Fire, the less Heat we are always sensible of; yet the law in which it decreases is very different from the general one, just now mentioned. For Experiments cautiously made for this purpose, plainly evince, that at a small distance from the heating point, the Heat on a sudden decreases prodigiously, but that at a greater, the proportion of the decrease is not so remarkable. Hence it appears very probable, that besides the power they have of acting upon other Bodies, the particles

ticles of Fire acquire another power, depending upon the relative motion which arises from their approaching very near to one another. For since those famous Philosophers, *Grimaldus* and *Newton*, have observed, that the Elements of Fire, as they tend towards opaque reflecting Bodies acquire new motions, as they come near their Surfaces, why may not the very particles of Fire be effected in the same manner by one another? But here I refer you to what has been already delivered upon this subject.

In the last place, the agitation, concussion, and compression of Fire, when it is excited by its *Pabulum*, and included within its aerial Arch, must enter likewise into the consideration: For by these the violence of it is very much increased, and indeed, always the more so, the stronger they are, supposing the Arch not destroy'd, as we took notice of before. And here, as we cannot by any means procure this agitation and compression of Fire, more conveniently, and more efficaciously, than by blowing, or driving the Air forcibly upon the Body of the Fire; hence Bellows are the Instruments in particular by which we direct this pressure of the Air upon the Surface of the Fire, and thus agitate the parts of it with a great deal of violence: But of this too we have treated already, when we was considering the aerial Arch that surrounds a burning Fire. And there likewise we saw, that if the Wind of a great many strong Bellows is directed from opposite parts upon the center of the same Fire, then the Fire will act with so much more strength upon the Body that is placed in that center, and consequently the changes it induces upon it will be so much more considerable. And hence the Assayers make use of this method in particular, when they want the greatest strength of Fire. In short, therefore, if the four methods abovementioned are called in to our assistance, and made to conspire in their efficacy, we shall by this means procure the most intense common Fire.

Fourthly,
by agitation
and compression.

These are the things, Gentlemen, which I thought principally necessary to lay before you, and to explain to you, in the natural History of Fire, particularly, as it is of use in the chemical Art. The disposing them in a proper manner, and setting them in an advantageous Light, has cost me a great deal of pains: Whether it has answered any valuable purpose, I leave you to judge. I think, however, that this is evidently certain from what has been said, that a chemical Fire, supported by the same *Pabulum*, and apply'd in the same manner, and the same degree, will always have exactly the same effect upon the same Bodies, either of adunation, or separation: And again, that unless these circumstances are first accurately determin'd, it is impossible to describe the action of Fire upon Bodies with any certainty. In giving an account therefore of any chemical operations, we must have a very careful regard to every thing that has been any where proposed in our Treatise of Fire: And thus at length the Art of Chemistry may be reduced to as certain and regular a Science as any other. Before, therefore, always to take notice of the degree of Fire; the succession of the degrees; the weight, and heat of the Atmosphere, and its action upon the Fire, either by draught, or artificial, or natural Wind; and then give an account of the Object: And a description formed upon this plan, will never lead a person, that would work after you, into mistakes. Give me leave now to add a few things that regard the nature of Fire. First, then, Fire, for its existence, does not stand in need of Air, Nitre, Fuel, Sulphur, or any other

Body.

Body. True *Naptha*, among Bodies we are acquainted with, is set on fire the easiest, and that, at a considerable distance from the Flame; as is likewise the purest *Petroleum*. *Journ. des Sc.* 1675. 53. Bodies that are rubb'd over with *Naptha*, and then set on fire, continue to burn, tho' they are immersed under Water. *Journ. des Sc.* 1683. 104. *Naptha* takes fire by the flame of a Candle placed within a Lanthorn, and thus prevented from coming into contact with it. *Phil. Transf.* N. 100. p. 188. Some Gunpowder was disposed in a machine into which Water could not penetrate, and with it was included a piece of Clockwork, which at a certain time, by striking a Flint against a Steel, should set the Powder on fire; it was then let down to the bottom of the Sea, and when, at the time expected, the Gunpowder took fire, they heard a very great rumbling noise, and saw a very thick Smoke, but there was not the least appearance of any Flame, *Sinclair. de arte Gravitationis*; which Experiment certainly deserves the most careful Observation, as it affords a good many *Phænomena* pretty remarkable. Sir *Thomas Sibbald*, in his *Scotia Illustrata*, gives us a very extraordinary account of the Lake *Strath-Erith* in Scotland, whose Water, he tells us, let the Cold be ever so sharp, never freezes before the month of *February*, and yet after that time, in the space of one Night, is often covered with a strong Ice; which *Phænomenon* seems to indicate that Heat increased in one place, produces a greater degree of Cold in another. And this again, which indeed was formerly taken notice of, seems more evidently deducible from another surprizing Observation of a little Rivulet that never freezes at all, let the Cold be ever so severe. *Phil. Transf.* N. 56. 1139. The same abridg'd, T. II. 335. But this opinion seems most of all confirm'd by the accounts we have from the Abbot *Boisotte*, in the *Journ. des Sc.* 1686. p. 336; and *Du Hamel*. in the *Hist. de l'Ac. Roy. des Sc.* p. 257. viz. that at about 5 leagues from *Bicanfon* in France, there is a Cave 300 paces deep, which in the space of one day, when the Weather is excessive hot, furnishes so much Ice, that the Waggon and Mules are scarce able to carry it away in eight; so that it rises almost to the thickness of four feet: And on the contrary, in the Winter time, it is full of dense Vapours, and a River runs in the middle of it, which is always frozen in the Summer. When any Vapours are seen in this Cave, they certainly prognosticate immediate rain. In Green-houses, likewise, and Stoves made to preserve Plants in the Winter, the greater the Heat is in any particular places, the more Cold there is in all the others. And the same is true of the places surrounding the Furnaces used for melting of Iron, and all the works with large Fires, especially, when the Heat within is most intense.

Thus, Gentlemen, I have endeavoured to explain to you the nature of that wonderful cause, which the great Creator has placed in the Universe, with a power of exciting those motions in natural Bodies, which are necessary for bringing about the extraordinary changes that are continually effected. As far as I have been able to get any knowledge of it by a laborious inquiry, I submit it to your examination. Its abstruse and mysterious nature affords us still matter for an infinite number of Discoveries. Let me excite your diligence therefore, to continue the prosecution of these inquiries, and afterwards to communicate them to mankind, that thus, by a more perfect knowledge of the Works of the Alwise Creator, we may better understand, and more justly reverence that
 2
 immense

immense Power and Wisdom, which infinitely surpasses all human comprehension.

Of AIR.

Order requires, that in the next place we should treat of Air; since both Nature and Art, by its concurrence and vertue, perform almost all their Operations. It is necessary, therefore, that we should be thoroughly acquainted with its nature and properties, if we would rightly understand the manner in which physical changes are effected. But as Air is more compound than even Fire itself, and consequently more difficult to be understood, hence the better to search out its hidden genius, we must here again proceed, as if we were intirely unacquainted with it, and observe the very same steps that we took in order to discover the nature of Fire. By the name Air then, we would have you understand that Fluid, which is hardly to be perceived by our Senses, but that manifests itself by its resistance to Bodies moved in it, and by its strong motion against other Bodies, at which time it is called Wind. By these Observations we know, that the Air rests every where upon the Surface of our Earth. All Men live in it, we enjoy it, and are perpetually nourished by it. The manner of our existence, and inevitable necessity constrain us, to breath in this Air, be it what it will; insomuch, that all the aids of Art are vain, and all that Nature can do for us, is fruitless, if we are deprived of it.

Air next to
be treated of.

If we will but examine into the manner, in which Nature operates according to the Laws which the great Creator has appointed, we shall plainly perceive, that this very Air is that grand, efficacious, and necessary Instrument, which universal Nature principally makes use of, in almost all the Operations she is perpetually engaged in. For in this, all *Species* of Bodies are placed; in this they move; and in this they perform all their actions; as well those singular ones which proceed from their proper and particular Natures; as those which are produced from their mutual, or as it is called, relative, disposition. Nay, there is scarcely any Liquid, as will hereafter appear by Experiments, which has not Air intermixed with its parts; scarcely any Solid, out of which Air may not be extracted by some Art or other. So that in short, it is very difficult to mention any known Operation of Nature, which happens without the assistance of Air, or utterly exclusive of it. The Operations of Fire, the Loadstone, Gravity, and the particular attraction, and repulsion of Corpuscles, may perhaps be alone excepted, as capable of being performed without it: To all others it is absolutely necessary. Whatever the chemical Art performs, it executes in the Air without any exception that I know of; unless, perhaps, the Alchemists will have it, that the Matter of the *Philosopher's Stone*, rightly prepared, and carefully lock'd up in the philosophical Egg, is intirely deprived of all crude Air, and is brought to its maturity, rather in *vacuo*, than in Air; for indeed, they all declare to a Man, that nothing is so great an obstacle to the maturation of this most beautiful Fruit, as the crude Air: But this may be ought rather to be understood, of the other Particles that are intermixt with the Air, than of the pure Element itself.

A second
universal In-
strument,

We know with the greatest certainty, that Fire which puts all things in motion, can scarcely be either collected, preserved, directed, increased, or moderated, without Air. Hence, then, if Fire requires Air, of consequence,
all

Because it
excites even
Fire itself.

all its Operations will require the same; so that without it, Fire would cease to operate, nor could be applied to other Bodies. But let me caution you, that I am here talking of that Fire which is excited and fed with inflammable Fuel, by the means of which, both Art and Nature execute their principal designs, and which, as has been proved by many Arguments above, stands in so much need of this Element.

It acts upon
Animals,
Vegetables,
and Fossils.

Whoever has leisure and inclination to take a view of the more general *Classes* of natural Bodies, will find, that Air is every where required to their vitality, growth, vigour, and action. For if their vitality consists in their propelling their humours through proper vessels, and by a peculiar power, converting the foreign Juices they receive into their own nature, or at least by a singular virtue applying them to their Substance, and thus increasing in their magnitude; I cannot help thinking it utterly impossible, that any one of these functions can be performed without the perpetual assistance of Air; but that its presence and aid is absolutely necessary to them all.

Air, how far
concerned in
the life of
Fossils.

The chemical Tribe, in particular, I am aware, will be surprized, when they hear me calling in the Air, in order to set forth the œconomy of Fossils; since their excluding simple matter seems to have occasion for the efficacy of Fire alone, to be capable both to act and undergo whatever is brought about in the *Species* of Bodies. But certainly, those who have duly considered the nature of things, have long ago understood that Fossils are brought forth, and multiplied, in the deepest recesses of the mines, and are thence protruded upwards, and that all this is accomplished by the exquisite power of the subterraneous Fire. And as this is certain, so likewise it must be allowed, that this subterraneous, vestal, and perpetual Fire, is there retained, collected and apply'd, by the Air alone. This, Gentlemen, is what I am particularly desirous to set before you in a proper light, as it is a point which has hardly been clearly handled any where else. Air then is a heavy, elastic, Fluid; dense, in proportion to the weights that compress it, acts more powerfully upon the same Fire, in proportion to its acquired density; expands itself in the same *Ratio*, as it is freed from compression; rarefies proportionably to the intenseness of the Fire that acts upon it; and insinuates itself into all things; and exerts chiefly all its properties, in those parts which are deep, and towards the center of the Earth. Hence, therefore, it always operates the more violently, the deeper and denser it is, and being agitated by the Fire, which by this very attrition of the Air is collected there in greater quantity, becomes the physical cause of the most violent compression, attrition, compaction, depuration, and union of homogeneous Particles: And hence, the Fossils which are generated there, are of a nature suitable to such a cause. Without this Air, none of these would be produced. And, perhaps, this is the sole reason, why they are only formed in those places. But more of this hereafter. What I have here said is sufficient, as it serves to let you see, that the presence and active virtue of the Air is requisite to all the Operations of Nature.

In Animals
and Vegeta-
bles.

Nor will it be any ways necessary, that I should explain to you the power of this Air upon Animals, and Plants; for some late very accurate Experiments have fully instructed us, that no Eggs of Animals, or Seeds of Plants, be they ever so ripe, pregnant, and the best of the kind, and cherished with ever so kindly a warmth, will ever bring forth the Embryo's contained in them, but will

will remain intirely unactive, if they are either deprived of Air, or are inclosed in stagnating Air in Glasses hermetically sealed. All small Plants, likewise, even the most minute Mosses; or aquatick Vegetables, when they are kept in a place void of Air, or when it is not renewed, presently wither and die. That the same also happens to all Animals, even to the smallest Insect, is true, beyond all contradiction. Thus then you clearly perceive the mighty influence of Air over all things.

An accurate knowledge, therefore, of the Air, by which its actuating properties may be understood, is absolutely necessary for the Chemist, Physician, and natural Philosopher; for by this means alone, we shall be able to comprehend a great many Operations, which are performed by Art, or Nature itself, their principal cause very often being some innate power of the Air, that exists nowhere else.

The knowledge of the Air therefore, very necessary,

In the mean time, there is not, perhaps, any natural Body, the perfect knowledge of which, is a matter of greater difficulty; because spontaneously, and of itself, it scarcely affects the organs of our Senses. This one may justly attribute to its exceeding subtilty, to which the dulness of our Nerves renders us insensible; inasmuch, as, even by the assistance of the most perfect Microscopes, we are not able to discover any thing in it. But there is yet somewhat else in the Air, which is still a greater obstacle to our rightly understanding its Nature, and that is, its containing so many various kinds of Corpuscles, that in the whole Universe, there is not found a Fluid compounded of a greater variety. Nay, when you have heard what I am going to deliver concerning this Element, it will clearly appear, that there is hardly any *Species* of Bodies that we are acquainted with, of which something doth not float about in the Air; Gold itself, the least volatile of all Substances, not excepted.

Though difficult.

It is highly necessary therefore, that we first of all take most distinctly into consideration, every single property of the Air, carefully avoiding all confusion: This done, and each being separately examined with due application, we shall by making an aggregate of the whole, obtain as true a knowledge of it, as the nature of the thing will admit of.

Method necessary.

The first property then of Air, which offers itself to our consideration, is its fluidity. This is so natural to it, that I do not remember ever to have heard of any Experiment, by which Air could be deprived of it. It is evident to every one's observation, that even in the sharpest Frost, when every thing, almost, is congealed, the Air still remains liquid; nay, in an artificial Cold, 40 degrees greater than ever Nature has been observed to produce, the Air still retained its fluidity, notwithstanding it was acted upon by such a prodigious excess of Cold. If you compress the Air with ever so great weight and force, too, into the utmost density, yet it does not then become solid by concretion, but remains equally fluid as before, and as soon as ever the compression is removed, it resumes its former liquidity: Nay, among the various coagulations I have discovered in the mixing of different Liquids together, which certainly have been a very great number, I have never yet met with one single Experiment, by which it appeared, that Air was coagulated into a solid Mass. I confess, indeed, one Noon, in frosty Weather, when the Air was very serene, I observed some very small Corpuscles floating about in it, glissening in the Sun, and by the variations of their little Surfaces sparkling with wonderful

In the first place Air is fluid.

coruscations ; but after a careful inquiry, I discovered, that these were nothing but little Glebules, consisting of Particles of Water, which before were dispersed about in the Air, but were now united and congealed, and thus appeared in form of a very subtil Hoar-frost. Were it possible, therefore, that Fire could admit of concretion with other Bodies, concerning which you may remember, I have treated already ; Air surely would appear to retain its fluidity much more obstinately than Fire itself. But, indeed, it rather seems probable to me, that there are in Nature two Fluids, the Elements of which will never unite with each other, nor will ever harden with any other Bodies into one homogeneous Mass : And these two are Air, and Fire. In the mean time, however, while I am talking in this manner, I would not have you think, Gentlemen, that I have forgot, that this very Air grows together, and unites with every kind of known Bodies, and so serves as a kind of Element in the composition of concretes : For this is sufficiently evident from the large quantity of Air, which of itself makes its way out of almost every Body, whilst it is reducing into its Principles, and is now-a-days, perhaps not so properly, called factitious. But you, Gentlemen, who have examined this Air with me, know very well, that it is contained in all known Liquors whatsoever ; that it penetrates together with them into all the recesses of concreted Bodies ; that thus at length, after a coalition of the whole, it remains lock'd up in the *Meatus's* of the Bodies, as it were, in very minute Vessels ; and afterwards, the Liquor in which it was convey'd thither, being dissipated, it is left there alone. Hence, then, you see very clearly, that this Air was not concreted there ; but only lay concealed, being retained by the including Body. As soon as ever, therefore, it can disengage itself from this confinement, it rushes forth intirely unchanged, and returns with all swiftness to its proper Nature. But this still appears more evident, if we consider common Water whilst it is freezing. Is there not hid in it a great quantity of invisible Air ? What becomes of it ? Why, as soon as ever the Water begins to form itself into Ice, and its Particles are press'd nearer, and united together, as they are now deprived of that degree of Fire, which is necessary to keep them asunder, and prevent their running into their natural union ; then, I say, the Particles of Air intercepted between the Corpuscles of Water, cannot congeal, but are pressed out of these interstices, are united with other Particles, are separated from the Water, collected in Bubbles, become again a most fluid Air, and thus evidently evince, that this Air was intercepted indeed, but not concreted, coagulated, or altered. The same thing being supposed to happen in the like manner in all other Bodies, the first property of Air, namely, its fluidity, is sufficiently made out.

The fineness
of the parts
of Air.

In the first place, now, the fineness or smallness of every Particle of Air, conduces to this its fluidity ; for they are so exceeding minute, that no one of them can be presented to the Eye by any Microscope whatever. And yet they are far greater than those of Fire ; for they can neither make their way through Metals, Glafs, Stone, or thick Wood, nor even through good Paper. And hence Air may be excluded or shut out from many places : Nay, it cannot so much as pass through those invisible Pores of Bodies, through which Wine, Oils, Water, Brine, *Lixiviums*, alcalious and acid Spirits, are able to insinuate themselves. These Observations are all evidently confirmed by the Air-pump. For if you put a leathern Ring on the brass Plate on which you fix the Receiver
out

out of which you exhaust the Air, and place the rim of the Receiver on the said Ring, then the weight of the Atmosphere, when the Air is exhausted from the cavity of the Bell, will press the rim of the Bell with so much force upon the Ring, that the external Air will not pass into the cavity through the ducts of the porous Leather, but will be intirely kept off; and yet, if you pour any one of the beforementioned Liquors upon the outside of the Leather, it will be immediately imbib'd, and it will instantly insinuate itself under the Glass into the *vacuum*; a manifest proof, that other Fluids, tho' somewhat thick and tenacious, can easily pass through the Pores of Bodies, that repel and keep off the Air. And the same thing is likewise easily made evident by an infinite number of other Experiments.

In the second place, these ultimate aerial Particles are so easily separated from one another, that this divulsion may be procured by a force so small, as does not fall under the notice of any of our Senses. Nor does it signify at all on which side, or which way you attempt this separation, it being always equally easy. This exceeding ready divisibility every one may observe, who considers the motion of a small polished Body through the still Air. Can you not move a Steel Needle with great facility in the circumambient Air, which way soever you please? And it is the same with all other Bodies. This property, therefore, you will give me leave for the future to call the lubricity or slipperiness of the Air.

The lubricity of the parts of Air.

However, when we carefully examine this lubricity on all sides, we discover, methinks, some tendency towards a union between these Particles, by means of which they readily run together into a mutual association; a slight one, I confess, indeed, and that may be easily destroy'd; but that is still a proper association. For upon examination, does it not appear, that whenever one single Particle of Air lies hid in any Liquid, nothing of it is any ways perceived; but as soon as ever a like Particle is united with it, there presently arises a Bubble from this union, which by a certain tenacity opposes its own dissipation? And if afterwards, another and another like Bubble meets with the former, is it not obvious to every one, that there succeeds, in proportion, a still greater Bubble, tenacious, as the former, of its magnitude and spherical figure? You will think, perhaps, that this is rather owing to the compressive force of the ambient Liquid; nor do I deny, that it may possibly happen by that means: But yet, the effort at least of the aerial Particles towards an union with one another, will be still greater than that between the Particles of Water and the very minute Particles of Air. The attraction, indeed, between these Particles, I acknowledge to be very small: Nay, but you will be apt to say, there is a repulsion between them, as the great *Newton* has plainly demonstrated: Nor do I deny it, and shall myself professedly treat of it by and by. In the mean time, however, it remains certain, that there is a power in these Particles, by which, when they are united in a spherical figure, they long maintain themselves in that figure against the force of the Bodies that surround them.

Their mutual attraction

For if we examine this inclination to cohesion more closely, we shall presently see, that the aerial Particles singly and separately considered, very easily suffer themselves to be mixed with any other Liquid void of Air, and that they obstinately abide in it, quietly resting in its interstices, in the same manner as

Air easily mingles with other Bodies.

any Salts are dissolved in Water. Besides it will appear hereafter, that a large aerial bubble, that is composed of many united Particles of Air, and placed on the surface of a Liquor intirely deprived of it, will resolve itself into its elementary Particles, and that these, when they are thus separated, will be carried into the empty pores of the liquid, and never gather themselves into a bubble again, unless by the additional force of a greater cause.

The imper-
ceptibility of
the Air,
what?

And hence, in the third place, we account for the Air's imperceptibility, already mentioned, to our senses. Nor would ever any one have thought of this Air which we now treat of, had not some great Bodies, and chiefly such as contain but a small quantity of matter under a large surface, been moved with their broadest surfaces through it. But in this case, the Air resisting the motion with a remarkable repulsive force, immediately manifests itself to be a hard body. And as these resistances, which are in reality actual repulses, vastly increase according to the augmented velocities with which the Bodies are moved, viz. as the Mathematicians compute in a duplicate proportion; hence it may happen, that this imperceptible softness of the liquid Air, may become as hard as a Stone. For if a person should take a very thin brass plate an hundred feet square, and with its surface directly forwards, try to carry it erect through the Air when it was still, with so great a swiftness, that it should move the space of two and twenty feet in a second of time, he would then find in this Air an incredible resistance or hardness, easily to be computed by *Mariott's* method. And if with this plate erect and quiescent, any one should receive the shock of a Wind rushing with the greatest rapidity, he would then likewise experience, with what hardness the Air is capable of striking, when it is hurried along so fleetly.

All this now is to be understood of the whole Air, as a compound, in which very great and heavy Bodies are capable of swimming, as appears by Birds and things of some weight carried away by the Wind, not to mention those of a lighter nature, as Dust, &c.

The Gravity
of the Air.

The next property of this Air, considered in the same manner as before, is the singular weight of its whole bulk; for in this respect all the parts together which in the aggregate constitute this Air, press with so gravitating a force towards the Center of the Earth, that by their fluidity, they form a Sphere around its surface, which we may properly enough call the Air-sphere, and which, on account of the very large quantity of Vapours exhaled into it, has hitherto by Philosophers been called the Atmosphere.

The Gravity of the Air, formerly discovered, *Torricellius*, that great *Florentine* Geometrician, ventured in the year 1643, to determine statically. After him, the famous *Otto Guericke* proved this Gravity by several experimental appeals to the senses, in the year 1655. That very ingenious Philosopher *Monf. Paschal* afterwards cleared it farther up; and the great *Mr. Boyle* rendered it more compleat. It was *Mariott*, however, who gave the beautiful finishing to it by the most curious Experiments of all; insomuch that now-a-days no part of natural Philosophy stands upon surer principles than this of the Gravity of the Air; for by the assistance of what these Gentlemen have done for us, the weight of the whole gravitating Air-sphere may be obtained to the greatest nicety, and expressed under the denomination of common weights.

It

It has hitherto, however, remained impossible to determine the weight of the aerial Body, comparatively with other Bodies, the weight of which is known. For upon inquiry, it very soon appeared, that no two equal portions of Air taken at the same time, but at different heights, were ever of equal weight; but that on the contrary the lower Air always outweighed the higher. And this holds so universally true, that the very same thing is observed from the surface of the Earth to the tops of the highest Mountains. Nay in the very same place you will hardly ever find, that an equal quantity of Air, at different times, will be of the same Weight; but even in this case there is observed a great variety, it sometimes weighing more, sometimes less.

How far discovered.

The Air-sphere in our climate, wherever it has hitherto been observed, is very considerably, and almost always wonderfully changing with respect to its weight, which never continues long the same. This variation is chiefly apparent whenever there is any Alteration in the Meteors in the Air, which is pretty frequent: For Rain, sudden great Showers, Fogs, Hail, Snow, Lightning, Thunder, Winds from various quarters, Storms, Whirlwinds, Drought, and the Changes of the planetary Aspects, are certain indications of the Atmosphere's becoming very soon of a new or different Weight. In this Affair the different Seasons of the Year likewise produce an incredible variation. By means therefore of this successive and incessant mutability, depending on such a number of causes, which are continually reviving, it comes to pass, that the weight of the Atmosphere never continues long the same. And hence an infinite number of effects about the Earth, which almost all depend upon the action of the gravitating Air, are in a perpetual vicissitude and inconstancy: So that this single Variation of the Air alone in point of Weight, is the source of a great many causes which produce different events. In the mean time however, by the help of very accurate Observations, continued for the space of above 86 years, we are now come to the knowledge of the greatest and least Gravity of the Air that happens in *Europe*. For upon examining, it has been found, that the greatest Weight of the Atmosphere is in *equilibrio* with $30\frac{1}{2}$ inches of Quick-silver in the Barometer, but that the least would raise it only to $27\frac{1}{2}$: So that the difference appears to be almost a tenth part of its greatest Weight, within which compass the perpetual variation of the gravitation of the Atmosphere is included.

Found to vary exceedingly.

This daily alteration now is owing to many peculiar, and perfectly different causes, but yet, however, such as are intirely certain, and may be come at by diligent Observations. And whenever this shall be accomplished, then we shall be able to form a regular notion of this Fluctuation, which at present is looked upon as intirely uncertain. From whom now should we so justly expect this, as from the famous *Nicholas Kruquius*, whose genius, learning, and indefatigable industry, highly qualify him for the cultivation of these studies, and whose aforementioned Meteorological Tables composed with infinite diligence and accuracy, shew us at one view all the causes concurring to every degree of the increased Weight of the Atmosphere. It were to be wished, that these so useful inquiries of this great master in Natural Knowledge, might meet with encouragement equal to their merit; lest when he is gone, we should look in vain for another that is equally qualified for the same discoveries.

To be brought under certain Laws.

Lastly.

And compared.

Lastly, it has been likewise observed, that the Weight of the common Air, about our Earth, at the time of the middle Weight of the Air-sphere, and in the most temperate season of the year, is to that of Water, as 1 to 850: But then this must be understood according to these conditions, otherwise it would be impossible to affirm any thing certain about it.

The effects of the weight of the Atmosphere.

In the first place, then, the Air resting with its whole weight upon our Earth, presses its surface with a perpetual force. And this pressure upon any particular Body is equal to that power which at the same time keeps up a perpendicular column of Mercury to the height it then obtains in the Barometer; the Base of which Column will be a horizontal Plane cutting a Pyramid whose *vertex* is in the center of the Earth, whilst its Sides touch the horizontal boundaries of the Body thus pressed by Air. Thus then may this power be every where exactly computed, by considering the height of the Quick-silver in the Barometer, at the time the computation is made, and the magnitude of the surface of the Body, the pressure upon which is required. And hence it is inferred, in the second place, that Bodies dispersed in the Earth, are so much the more pressed by the incumbent Air, the nearer they are to its center; for it is evidently demonstrated in hydrostatics, that the pressures of liquids upon their bases are in proportion to their perpendicular Altitudes. Hence, therefore, if we consider the Air as a Liquid, every where homogeneous, and incompressible; then the proportion in which Bodies are compressed in every part of the perpendicular from the surface of the Earth to its center, might be easily discovered: But as the elastick power of the Air brings a great many very different considerations into the subject, we shall speak particularly of that matter by and by. In the third place, it appears on the other hand that all Bodies, the farther they are raised above the center of the Earth, the less in proportion they are affected by the pressure of the Air. But it must be observed farther too, in the fourth place, that Bodies in the very same situation, will be more closely compressed together, as the weight of the Air is augmented, according to the abovementioned observations. And fifthly, as soon as ever the same Air decreases again in its weight, the pressure upon these Bodies will be proportionably diminished. Sixthly, all those Bodies, therefore, that are exposed to the Air are never long compressed with the same external force; but the compression they suffer is varying continually; with this limitation, however, that the difference of the pressure is never found in the same place to exceed one tenth of the whole; within which tenth is included the whole compass of this variation. Seventhly, therefore, the Air itself, while by resting on all Bodies it thus compresses them with various forces, must likewise in proportion be repressed by them, provided they are elastic, or such as have in them an innate effort to expand themselves, or to recover that size which is the proper effect of their natural energy. And hence, therefore, it appears likewise, in the eighth place, that in all Bodies which are situated in the Air there is a perpetual oscillation of their Particles corresponding to the reciprocal augmentation or diminution of the Weight of the Air. This oscillation is but small indeed, as being confined within the length above mentioned, for the compass of its variation; but still it is a proper oscillation, and is almost continual. But we have before, in the History of Fire, taken notice of another tremulous vibration in the Particles of Bodies, produced by the various vicissitudes of

Heat

Heat and Cold, which, therefore, in conjunction with this of the Air, must bring about very considerable and continual effects. We acknowledge, therefore, two perpetual causes of the constant, internal motion of all the Particles of elastic Bodies, viz. Fire, and the Air-sphere. In the ninth place, however, it must be remarked, that upon Bodies, which are absolutely soft, if any such there are, that is, that are intirely destitute of a power to recover their former figure, when the force that presses them is removed; and upon Bodies, such as Water, which cannot by any external Weights be reduced into a smaller space; upon such, I say, the compressive force of the Air-sphere, with regard to its increase or diminution, has no effect; and consequently, upon such Bodies, the reciprocal Oscillation we have mentioned, will be of no efficacy. Seeing then that Fire acts equally, nay more upon these very Bodies, than on all others, it plainly appears, that the power of Fire, on this account, is to be regarded as far more universal than that of Air, and consequently of any other Body.

It will now be of service to us, if with an eye to Chemistry, we take a view of those effects which the external Air produces, considered as a fluid and gravitating Body together; for in this light it evidently appears, that it must rest with some force upon the outward surfaces of all Bodies, as has been just now explained. Hence therefore, in the first place, it will insinuate itself between the surfaces of all Bodies, the distances of which from one another leave interstices so wide for the admission of the external Air, that by its subtlety, or the loose texture of its parts, it may be able to enter into these little spaces. Hence, likewise, it is evident, that all the little invisible *Meatus's* of Bodies, which are qualified in the manner just mentioned, though they appear to our senses to be perfectly empty, are in reality full of common Air. And since this Air must certainly in those Interstices perform all the effects which are proper to it; hence an infinite number of the operations of Nature will of consequence depend upon it. Secondly, it is a curious observation in Hydrostaticks, that the heavy and fluid Air presses upon every side of Bodies with an equal force, whither the horizontal, vertical, superiour, inferiour, or oblique. This is demonstrated in that Science: But as Chemists are often unacquainted with those studies, I have thought it proper to give an ocular demonstration of a truth which is of such importance in the Chemical art. I take then three glass vessels; one cylindrical, A; another conical, B; the third, C, running, like a bolthead, from a spherical bottom, into a long, cylindrical neck. Under these three you easily conceive, all sorts of simple vessels may be comprehended, as is easily demonstrated by Geometry. Be pleased to observe, then, in the first place, I fill the Cylinder A with fair Water exactly up to the brim. Upon the surface of the Water then I put a piece of single clean paper, D, just big enough to cover the mouth of the Vessel, and this with the palm of my left hand I press equally on the surface of the Water, so that between that surface and the paper no Air can be retained. Then with my right hand I invert the vessel, as you see, in such manner, that the palm of my left hand remains close upon the paper. Having in this manner turned the vessel upside-down, so that the mouth of it, which is covered with paper, is at the bottom, I gently remove my left hand, and with my right I hold the Glass as it were freely suspended in the Air: And you see, that not the least drop of Water

The effects of Air considered as a Fluid and gravitating Body together.

runs

runs out of the Vessel, but that the Paper remains as closely pressed to it, as if the Palm of my Hand was still apply'd to it. Observe farther, I gently turn the Vessel from this vertical to an horizontal position; and does not the Water still remain in the Vessel, and the little Paper still closely adhere to the mouth of it? These things you plainly see. Do you not therefore acknowledge, that the pressing power of the heavy and fluid Air, has the same effect upwards, laterally, and downwards, and that it presses a Body placed in it with the most exact equality in every point of its surrounding Surface? And therefore, that the Air which is perpendicularly under the mouth of the Vessel, has the same force in its effort upwards upon the Paper, as the Air which horizontally presses upon the Paper, and even as that which bears upon it vertically? This effect of every heavy Liquid, the great *Archimedes* observed very nicely, as he did every thing else, and raised a great many very curious demonstrations upon it. There is in reality no end of the truths, which may be hence deduced. But these we leave to be explained by proper Masters, whilst we Chemists thus enjoy the benefit of them. The same thing again you see now in this conical Vessel. The Base of this glass Cone B being open, and its vertex E close, I fill the Vessel compleatly up with Water, apply with the Palm of the Hand the Paper D, and turn the Vessel till the Base is undermost. I now take off my left Hand, and suspend the Cone with my right. The Paper you see does not drop off; nor does the Vessel lose one drop of Water. I gradually change the vertical into an horizontal position, and still nothing runs out, but the Paper remains as closely fixed as ever. Now, if the *vertex* of this conical Vessel was open, and the *Base* closed up, and the like inversion were made of the Vessel, the very same effects would follow. This then you likewise see the truth of. Lastly, then, I proceed exactly in the same manner with the other Vessel, and you are Witnesses, that the Experiment succeeds exactly as the preceding. Since this then is the case, you conceive, Gentlemen, with me, that the Air, therefore, pressing equally upon every point of the Surface, enters likewise equally into all the Pores and Ducts to which it is applied, whether they are in the upper, lower, or lateral Surface, or in any oblique position whatsoever; and that it presses likewise with an equal force in all those different parts, with this variation only, that that part of the Air that is lowest, always presses more forcibly upwards, the lower it is, that is, the nearer it is to the center of the Earth. In the third place, the Air by these its properties, compresses all Bodies on every side, fills up their cavities, and forms upon them a Surface, which has a very strong coercive power. Hence, in the fourth place, it comes to pass, that this Air, whether external or internal, which from its fluidity is supposed to be continually in motion, and by its gravity is applied to the external parts of fluid Bodies, causes a continual attrition, concussion, and agitation of their Surfaces, by this means mixes different Fluids together in a wonderful manner, applies and excites their reciprocal powers, and thus produces continually a great number of effects. Fifthly, however, it alters not the figure or shape of the Bodies which are exposed to it, excepting only so far as there are empty spaces in them, in which there is no Air. For if in such a case they are not able to resist this force of the Air, they will, by the pressure of it, be reduced into smaller spaces, the corporeal parts will run together into a closer union, the whole Mass become more solid, and the former bulk will appear

pear diminished. But this case excepted, the Air, with all its force, is not able to break the weakest and most brittle Body that is fill'd with it, and placed in it; for as much as it presses on one part, so much exactly it sustains on the other, and thus preserves all Bodies *in equilibrio*. In the mean time we know, that the motion of the Air is always considerably swift; which is particularly evident from an Observation made in a Room that is darkened, when the Air is very still, and then illuminated only by a single Ray let in at a very small Hole: For if then any one standing on one side of the lucid aerial Cone, turns his Eye upon that luminous part, he will really be surprized at the motion of the Atoms, which with a considerable and perpetual rotation, are carried about hither and thither, and most rapidly confounded with one another. Hence, then, we are the more induced, with great probability, to conclude, that all those in the external open Air are constantly in a greater agitation, and consequently, that the motion and attrition among themselves, and upon the Surfaces of other Bodies, is very considerable, inasmuch as the motion is continual, and the gravitating force equal to the pressure of a column of Water 33 feet high. And hence we may easily conceive in the sixth place, how strong must be the attrition and motion of the Atmosphere upon the Surfaces of all Bodies; especially, as often as it is agitated by Fire, or Storms. Let us suppose, that in an *Area* of one foot square, there gravitates the weight of 2080 pounds; what a mighty pistil is this? Let this now, in a great storm, be mov'd with such a rapidity, as that in a second of time it shall run the space of two and twenty feet, will not the force of this weighty pistil, in the attrition of Bodies that are under it, be incredibly great? Thus, therefore, an infinite number of very powerful physical changes are effected by these causes, which not being regarded by the Chemists, they have, in order to account for these effects, in vain invented, I know not what very abstruse, and plainly fictitious ones; whilst in reality, the whole matter depended intirely upon these simple ones we have just mentioned, nor required such very extraordinary ones, assumed without any foundation. In the seventh place, it should be particularly remarked, that the ultimate Particles of the Air cohere together in such a manner, that they are not very readily to be divided into their minute parts, so as to insinuate themselves easily into the smallest passages, but these are required considerable large, before this penetration happens. This I clearly demonstrate to you by the following Experiment. I have here in my Hand a glass Thermometer, filled up to the brim with Water. 'Tis four feet long, and the neck of it is so narrow, that the diameter of the Tube is only the eighth part of an inch. This, now, I invert so that the mouth of the Tube is downwards, and yet you see that not one drop of Water comes out, but on the contrary, it remains as unmoved in it, as if it had been very carefully stop'd. But again, the Barometer of *Torricellius*, with the suspended Mercury, does not transmit any Air into the *Vacuum* which is left at the upper part of the Tube, tho' the Air exerts such a mighty force upon the Surface of the Mercury, in order to fill up this empty space: For here the Air cannot be divided into so minute parts, as to enter the interstices of the Mercury, but remains excluded. If the same Experiment is made with Water, or even with Spirit of Wine, the event will be always exactly the same. From all these Observations, therefore, it is clear, that the Air is not easily to be divided into its minute parts; for

otherwise those parts would pass through the Pores of these Liquors, within which the Particles of Air may be disposed, and lie concealed, as will appear manifestly hereafter, when we shall professedly illustrate by Experiments, how the Air may be extracted from the inner Cells of Bodies, in which it is lodged. But in the eighth place, I shall endeavour to shew you, the magnitude of those Bubbles by which the Air ascends through Water contained in Tubes. You see, I hold here a glass Thermometer which has a neck pretty long, and so wide, that the diameter of the mouth is a quarter of an inch. This being full of Water, I turn upside down. What is the consequence? Why you see the Air ascending through the Water in the neck of this Vessel, rises only in large Bubbles, nor does by any means divide itself into little ones; and besides, these Bubbles, which are of a very discernible size, stop here and there in the neck of the Vessel. There must therefore either be a power of association in the Air, or else a repulsive power in other Liquors, with respect to the Air, by which they drive the aerial Particles into mutual contact. To make this still plainer, I will exhibit to you another Experiment: You see here a glass Vessel, open at the top, in which there is pure Alcohol. This very small glass Vessel, formed like a Bolt-head, with a Bulb and narrow Neck, is full of fair Water. This now, into which the Air does not presently enter, whilst I turn it up, I thus invert and immerse the mouth of the neck which is now downwards into the Alcohol: And don't you evidently perceive the Alcohol ascending through the Water into the belly of the Glass in flow oily spirals, and the Water descending into the Vessel which is now abandoned by the rising Alcohol? The Alcohol now rests in the upper part of the Vial, whilst the insipid Water taking the place which is quitted by the former, descends from that into the Vessel. Hence, therefore, I look upon it as certain, that the Particles of the Alcohol and the Water, are, by vertue purely of their fluidity and gravity, most easily admitted into, and transmitted through those interstices, which are left between the Elements of both; but that the admission and transmission of the Air is exceeding difficult. But this will be made still more evident by this other Experiment: Instead of Alcohol, I have poured Oil into this Vessel; and the Vial being quite full of Water, and turned bottom upwards, as before, I put the neck of it into the Oil. Could you now have expected what you see? How prettily do the Globules of Oil ascend through the Water from the lowermost to the uppermost parts, till all the Oil, after much struggling, has risen out of the lower Vessel to the top of the belly of the inverted Glass. The event will be exactly the same, if I fill the Glass with strong saline *Lixiviums*, and immerse it after the same manner in Alcohol, fair Water, or Oil. Of this property of the Air, therefore, which we particularly recommend to the consideration of the Chemists, we are likewise assured, by comparing it with other Fluids, *viz.* that the Particles of Air collected together in any quantity, are not by far so easily separated from one another, as the Elements of any other Fluids that we are acquainted with. And hence, it is likewise evident, that the minute Particles of Air cannot easily be intermingled with other Liquids, but rather run together within them, and thus discover themselves by distinct Bubbles, or a collection of them which then becomes froth: Notwithstanding which, however, when the single Elements of Air have lodged themselves, separately, in the Pores left between the ultimate Particles of other Liquids,

quids, it is a very hard matter to set them free again. This we are very certain of, who have seen how difficult it is wholly to fetch out the Air which lies in this manner concealed in Mercury, and are sensible of the wonderful effects, with which this separation is attended; for *Hugens* long ago observed, that Mercury freed intirely from Air, has kept suspended in the Barometer to upwards of 50 inches. But of this property of the Air, I shall professedly discourse to you hereafter. Thus, then, I have faithfully laid before you those properties of the Air which it has in common with all other Bodies; and at the same time have carefully explained to you its efficacy, considered in this view, upon those Bodies which usually fall under a chemical Examination; having only added some Observations, which I could not avoid, concerning its miscibility with other Fluids. Let us now chearfully proceed to the consideration of those peculiar properties which are possessed by the Air alone.

The first then that here offers itself to our observation, is the elasticity which Physics has discovered in it. This is that singular quality, by which all known Air, possessing a certain space, and being confined there in such manner that it cannot escape, will, if it is press'd together by a determined weight, reduce itself into a less space, which will be always in a reciprocal proportion to the quantity of the weight that acts upon it; with this circumstance, however, always attending it, that it will constantly, by a spontaneous expansion, recover again the space it hath lost, in proportion, as the compressive force is diminished: And when this force comes to be the same as it was in the beginning of the Experiment, then the aerial Mass will always infallibly expand itself throughout the whole space, that it before filled up, provided, that no other cause, in the mean time, shall intervene to hinder it. If the pressure is lessened, Air extends itself to a larger space; if it is increased, it reduces itself into a less.

The elasticity of the Air

Now such a disposition as this, Gentlemen, yielding so readily to such a compression, and yet recovering itself with such a spring, I don't remember to have been observed in any other Liquid hitherto examined. 'Tis certain, no such thing is discovered in Alcohol, Oil, Water, Spirits, or any *Lixiviums*. For tho' all these are easily contracted by Cold, and dilated by Fire, yet they yield not to weight by proportional retreats into closer and closer spaces; nor being freed from their pressure, do they expand themselves perpetually. This, therefore, is the peculiar property of Air alone. And hence it merits an exact explication, which you will sufficiently understand, if I clearly lay before you, from *Boyle* and *Mariotte*, the wonderful Law of this elasticity.

Is peculiar to it

These Gentlemen, then, have discovered, upon the evidence of elaborate Experiments, that the following is to be looked upon as the principal Law of this property; namely, that the Air by compression is contracted into spaces, which are always exactly so much smaller, as the compressing weights are greater. Hence, therefore, the density of compress'd Air is always in proportion to the compressing weight. Let us, for instance, suppose a cylindrical Vessel full of Air, and the inside of this Vessel to be so very firm and immoveable, that it will not in the least give way to the pressure of the contained Fluid. Let the *Base* of this Vessel be exactly an *Area* of one *Rhineland* foot, its height 64 inches. The Air then contained in this Cylinder, will on its upper Surface sustain the pressure of the Atmosphere, which we will suppose to be 2112 pounds *Troy* weight;

Under a certain Law.

L 1 2

and

and the Air which fills up the capacity of the Tube, will be the same as the common Air. If then the upper surface of this Air should be compressed by a perpendicular column of Mercury of 29 inches height, the pressure in such case, would be twice as great as it was before from the Air sphere alone. And according to the increment of the pressure, the Air compressed would be reduced into smaller spaces, in the proportion hereunder mentioned.

lb. 2112	press the Air so as to make it fill this Cylinder	1
4224		2
8448		4
16896		8
33792		16
67584		32
135168		64
270336		128

and so on continually. Hence, then, it very clearly appears, to such as consider the thing, first, that it is not a very easy matter by this method to reduce the common Air into a space 64 times less than that which it naturally possesses; since so enormous a Weight, and so firm a Tube 203 inches high, are required for this purpose; and the Air in point of weight, would be then to Water, about as 1 to 13. But if the weight here assigned to the Atmosphere, viz. 2112 pounds, was eleven times doubled, then the Air, which by this means would be reduced into a space 1024 times less, would be a great deal denser and heavier than Water. In the second place, it appears certain, that this Air can never be absolutely reduced into no space at all, tho' the weight, and consequently the compressure caused by them, should be ever so immensely increased, as a view of the Table annexed sufficiently demonstrates.

How far this
Law ex-
tends.

Besides, I shall, perhaps, hereafter make it appear, that one thousandth part of the common Air, at least, consists of aqueous, spirituous, oily, saline, and other Particles scattered through it, which being united together by this compressure, form at length a Body no farther compressible. So that on this account, it seems to me quite incredible, that common Air can ever be reduced into a space, a thousand times less than it usually takes up, without being compress'd by this means into nearly solid Masses; which indeed, with respect to the elastic aerial part, may be always contracted somewhat closer, but never in a *Ratio* with the compressing weights, because then the Bodies too, mingled with the common Air, must likewise follow the same Law of elasticity, of which we sufficiently know from Experiments they are absolutely incapable. But as these Particles in the Body of the common Air, which are not compressible, rarely make one eight hundred and fiftieth part of the whole, it is nothing strange, that this proportion has always been observed, in the Experiments which have been made, concerning this Law: The reason of which will immediately appear, when I come presently to lay before you the Experiments of Mr. Townley.

This Law,
in the first
step of the
Experiment,
is very visi-
ble.

Let us then in the second place consider, that it is an easy matter, by the means of compressing weights, to contract the common Air into a space, less by half than that which it took up before: And in this step of the Experiment it has been very accurately observed, that this double condensation was effected by doubling the weight. For in this case, those compressible Corpuscles which
take

take up only a thousandth part of the first Space make so little alteration, that they utterly escape the notice of the Senses. The rule, therefore, in this first step answers exactly to the Senses, and is capable of ocular demonstration.

But in the third place, those who are acquainted with these things will easily apprehend, that the less the Spaces are, into which the Air is compressed, the greater gradually does the difficulty become of demonstrating this Law. For since we are informed from Hydrostaticks, that the pressure of heavy liquids on the bottom and sides of their containing Pipes is always in proportion to their perpendicular Altitudes; hence you readily conceive how mighty strong the Tubes must be, for the carrying on of these Experiments, till the Air is reduced into the one hundredth part of its natural Space. But you know likewise, it was long ago discovered by the Academy *del Cimento*, that even metalline vessels have been enlarged in their capacities, by being filled with ponderous Liquids: How much more certainly then must this be the case in Glafs? And yet you very well know, that it is requisite, that the instrument here made use of, should be made of Glafs, that the height of the compressing Mercury in the inextensible Tube may be compared with the height of the Air, compressed by the Mercury; because it is only by an accurate knowledge, and an exact comparison of these heights, that we can come at the thing we are in search of. But what a vast deal of caution and accuracy is here again required! The Tube must be very long, not dilatable, every where exactly of the same figure, and perfectly transparent. The Air to be compressed, throughout the whole course of the Experiment must continue exactly of the very same degree of Heat, for every little increment of it in this case will act by so much greater an expansive power as the Air is more condensed by the compressing weights. And, indeed, not only in this, but in the other parts of Natural Philosophy likewise, our Experiments are performed amidst a thousand concurring causes; any one of which being neglected, our conclusions upon the events will vary from the truth.

Afterwards
always harder
to be discovered.

But that you may have still a juster notion of the matters we are handling, give me leave to lay before you the method by which the Philosophers discovered this Law of the Air's Elasticity. This will enable you to judge more accurately, what is justly to be thought of this Law, and of the extent of it, in which point, perhaps, they have carried it rather too far. The great *Boyle*, then, took the double-legg'd Tube, A B b C, inflected as you see in the Figure, open at A, and hermetically made at c. He took care it should be every where exactly of the same capacity in b c, and should be made very thick and strong. The Leg b c, was 12 inches long, and was accurately divided into Lines: The other, AB, contained a good many feet. By pouring Mercury then into the Tube at A, and by this means condensing the Air in b c, from 48 to 3, or from 16 to 1, he found, that the Space into which the Air was compressed was always diminished in proportion to the Increment of the Weight. See *Boyle* against *Linus*, p. 60, &c. *Mariotte*, of the Nature of Air, p. 151, 154.

The discovery
of this
Law.

Pl. VII.
Fig. 2.

As this therefore was the manner, and this the extent of the Observations, by which the condensibility of the Air, in respect of the compressing Weights, was discovered, every one sees, that this condensation was not carried beyond one sixteenth of the whole. Nor, for my part, have I ever met with any authors that have made any farther advances in this matter, who have published their Experiments. The famous *Dr. Halley*, indeed, and the celebrated Academy *del Cimento*.

With caution.

(Mem.

(*Mem. de l'Academ. Roy. des Sc.* 1703. p. 102.) inform us, that the Air cannot be condensed beyond $\frac{1}{800}$ part of its natural Space; but the Experiments, by which these great men were able to condense the Air so far, as that after such condensation, it could not be reduced into a less Space, have not yet been made publick. Whatever those Experiments were, however, this is certain, that the Air so compressed, and reduced into smaller Spaces, will again expand itself gradually into greater Spaces, exactly in proportion to the decrement of the compressing Weight, which *ratio* is constantly observed to hold true. And, indeed, the ingenious Mr. *Richard Townley*, as the great *Boyle* relates in the place just cited, discovered by Experiments that might be depended upon, that this spontaneous expansion of the Air, upon the diminution of the compressing Weights, did most exactly follow this Law from 1 to 32. Upon the evidence, however, of these truths, thus far indeed certainly demonstrated, let us take care we don't launch out too far, and absolutely assert, that this Law, namely, that the Spaces taken up by the compressed Air, are in a reciprocal proportion to the compressing Weights, always holds true. For indeed, I confess, it is my opinion, we are at as little certainty on this point, as the most illiterate person whatsoever. Let us proceed, therefore, and set forth what we certainly know of it from experimental proof. In the first place, then, we are assured, that the common Air may be reduced into a Space sixteen times less than it took up before; and that therefore it may be condensed in this proportion. In the second place, we are equally certain, that such is the disposition of this Air, that it may, by expanding itself, be diffused into a Space, two and thirty times greater, and fill that Space with as equal a distribution of its parts as before. In the third place, that this contraction of the compressed Air into a Space so much less, than what it possesses naturally, is owing only to the force of the externally applied Weight, by which it is reduced into so small a Space. And again, in the fourth place, that the same Air being by any means freed from the force of the compressing Weight, does, by the power of its own peculiar nature, without the intervention of any other cause, excepting only the Fire that is present with it, expand itself in such a manner, as always exactly to recover so much Space as it had before lost by the compressure. And in the fifth place, which is pretty extraordinary, that this virtue of expanding itself, peculiar to the Air, does always remain after the greatest compressure, since it always continues so accurately proportional to the quantity removed of the pressing weight. In the sixth place, that its capacity too of compressibility is equally indestructible; for after the Air has been rarified, by removing the compressing Weights, to two and thirty degrees, there has still remained in it, so rarified, a property, by which it was again capable of being compressed, as before, by the like force of the former Weights. In the seventh place, we know from the most certain Experiments, that this dilatability, and compressibility of the Air, by the sole action of Weight, answers accurately, as far as our senses are able to judge, to the increment or decrement of the compressing Weight. In the mean time, however, the Philosophers of *Great Britain* and *Italy*, men formed by Nature for unraveling these mysteries, have declared in their Writings, that the common Air cannot be rendered above eight hundred times denser. This, therefore, we learn likewise from their Experiments, which they have hitherto concealed. Of the great probability, however, of their assertion, I shall discourse my self by and by,

by, when I have communicated to you some things that are known for a certainty, concerning the Corpuscles which float about in the common Air. In the eighth place, therefore, Spaces filled with the same quantity of Air, are so far in a reciprocal proportion to the compressing Weights. In the ninth place, this is always true, as well in that Air, which is reduced into a Space sixteen times less, as in that which is only compressed by the common Atmosphere. In the tenth place, it appears, according to the Experiments of Mr. *Townley*, already mentioned, that this proportion never varied in all the compass from 32 to 1. In the eleventh place, therefore, it is exceeding probable, that the same rule obtains likewise in a farther condensation; but so as that by little and little, as the Air is more condensed, greater Weights are requisite, for the same condensation, till at length all farther compressibility is utterly at an end. In the twelfth place, we see that the Air so contracted and compressed, does not transpire, or penetrate thro' Glafs, nay, indeed, cannot pass through the pores of the Mercury; for it still remains in the same part of the Tube, though by means of such an incumbent Weight of Mercury, it is reduced to so much greater density. Nay farther, tho' the Air, by means of Fire, is rendered warmer, and made to elevate the incumbent Mercury, it does not then penetrate either through that, or through the Glafs.

Another law, which we find to obtain in the Elasticity of the Air, is that it cannot be destroyed; inasmuch as upon examination by every kind of Experiment, it has always remained elastic; nor are its elastic parts either by long rest, or the greatest pressure, ever so disposed as to lose the Elasticity we have been just explaining. For Mr. *Boyle* and *Mariotte* having, with a particular view to this matter, kept common Air strongly compressed, and shut up in a Wind-Gun, found, upon their setting it again at liberty, that it was perfectly as elastic as it was before. And lately, that great Geometrician *Robervallius*, examining Air which had been shut up for the space of fifteen years after the like manner, found, that it had not lost any thing of its Elasticity. See *Du Hamel. Hist. de l'Ac. Roy. des Sc.* p. 368. But it will hereafter farther appear, that even those elastic Particles of Air, which are detained in the interstices of the most internal parts of fluid or solid Bodies, do, when they are set free from those confinements, and are afterwards united to other Particles, exert again that Elasticity, which they then seemed so utterly to have lost, as not to give the least indication of retaining it. For as soon as ever they recover their liberty, they produce incredible effects, which can be attributed to their Elasticity alone, and thus evidently make it appear, that neither time, nor rest, nor even their supposed concretion with Animal, Vegetable, or Fossil Substances, is ever able to destroy this wonderful property of the Air. In the mean time, however, we learn from the same Experiments, that such is the nature of Air, that its elastic Particles, when separate and by themselves, may be so united to other Bodies, by which they are intercepted, or at least may rest in them in such manner, as not, for Ages together, to produce any elastic effect; and that yet, upon their being freed from those Bodies, and mingled with others of the like nature, they demonstrate, that they have intirely retained their Elasticity. Hartshorn, for instance, may be preserved for several ages; and yet upon a chemical examination of some which had been kept above fifty years, and by this means was grown exceeding hard and dry, it's surprizing what a quantity of elastic Air it yielded in its resolution! Hence, therefore, it is very probable, that one single, elastic, aerial Particle

The elasticity of the Air not to be destroyed.

Particle is not elastic, with respect to the increment or decrement of incumbent Weights; but that this Elasticity then only has being, when two such Particles of Air come to touch and repel one another; and that, consequently, if these elastic, aerial Particles were so far distant from each other, as that this repelling force should utterly cease, then this whole Liquid would, for that time, neither spontaneously expand itself, nor in the least resist any compression; but would then only exert this power, when, by being pressed closer to one another, they should begin to come within the sphere of each other's activity. One aerial Particle, therefore, would have nothing of this elastic power; but it would be only the joint effort of several. Hence then, in all appearance, the elastic power of Air ought to be regarded as constant and immutable.

Air condensed continues fluid,

But in what manner, or to what degree soever, this Air has been condensed by the utmost power of Weights, it has always remained, even in that condition, very fluid; for after it has been contracted into the greatest density, it has constantly restored itself again in all its Particles, with the same facility, so as to fill up exactly the former Space; all the Particles retreating with the same ease with which they before came together. Since, therefore, by every Experiment that has been hitherto made, this property has been always found to take place from 1 to 520,000, we may fairly assert, that the Fluidity of the Air, in all the large compass, from the most rarified, to the most condensed, remains without alteration; and that therefore it is neither capable of being consolidated by the intensest Cold, or the greatest degree of compression.

The Elasticity of any portion of Air of equal force with the whole Body.

But nothing now in this elasticity of the Air seems a greater paradox to persons not Masters of this affair, than what Mr. Boyle has evinced with so much certainty; viz. that the elastic Power which prevails in any particular portion of the Air, can, without any greater condensation than what is owing to the compressing Air itself, sustain all the force of a whole column of the incumbent Atmosphere: And secondly, that this elastic Power, in such a very small portion of Air, can, by expanding itself, repel the Bodies which compress it, with as much force, as that which is exerted by the whole external Body of Air. The truth of these assertions, I prove to you by the two following clear and easy Experiments that are borrowed from Mr. Boyle himself. You see this Barometer, which contains in its hollow Tube, Mercury elevated to 28 inches, the lower part of which is immersed into the Mercury contained in this cylindrical Vessel. And you see likewise, that this Vessel is so contrived, that by means of a little Cock, all intercourse between the external Air, and that little Portion which is in the Vessel above the Mercury, may be cut off at pleasure. If now I so turn the Cock, as that neither any of the external Air can get into the Vessel, nor any of the Air in the Vessel can get out to the external Air, then we are sure, that the external Air can no longer act upon the Air in the Vessel; and that only the Air which is inclosed in the Vessel above the Mercury, can press upon the Surface of the Mercury in the Barometer. And you see evidently, that the height of the elevated Mercury is exactly the same as it was just now, when the weight of the whole Atmosphere press'd upon it. That elastic Power, therefore, which is in the little portion of Air contained within this Vessel, can sustain as great a weight of Mercury, as the whole incumbent Atmosphere. But if you please to observe again, you see, that while I am heating the Vessel remaining just as before, the Mercury in the Barometer rises higher and higher every

every moment. How comes this to pass? Why thus: The Air inclosed in the Vessel cannot make its way out; by the action therefore of the Heat upon it, it acquires a greater degree of Elasticity, expands itself, presses with more force upon the Surface of the Mercury, and by this means makes it ascend. Nor does it at all signify, how little a quantity of Air is contained in this Vessel above the Mercury; for the effect of the elastic, or heated Air, will in this case be always exactly the same. But in the second place, if this Vessel, with the same *Apparatus* remain shut, and is so nearly filled with Mercury, as to have but a little portion of Air above it, and then a barometrical Tube, open above and below, is fixed in the Vessel in such a manner, that no Air can either get in or out by the sides of the Tube; then, if the Air in the Tube is exhausted with an Air-pump, the Mercury in the Tube will rise to near * 28 inches, in the same manner as if the whole Atmosphere had press'd it up into the empty Tube. See upon this head *Boyle of Mechanical Experiments*, Vol. I. Part II. from Page 1. to 24. And this very efficacious power of the Air, the Chemists ought by all means to have a particular regard to; since 'tis certain, that in all chemical Operations performed with Fire in close Vessels, this elastic force produces wonderful, and often very terrible effects; acting with a violent compressive force upon the contents, often bursting the Vessels asunder, and producing many other surprizing events.

A very little portion of Air, therefore, wherever it is closely confin'd, is capable of producing the very same effects, as are owing to a very large quantity in another place. For if any portion of common Air is perfectly intercepted within a cavity that is easily compressible, it will there sustain, and from that place wholly keep out the large pressure of the Atmosphere. And whenever the Air in that place is heated by Fire, or freed from its external pressure, it immediately, by expanding itself, becomes so rare, as to produce such effects as are equal to those of the greatest Body of Air.

Hence the smallest portion of Air is equal, in its elastic force, to a large one.

Another Law, therefore, of the elasticity of the Air, is this, that when it is condensed in a certain and determinate degree, it acquires by the application of Heat, a greater power to expand itself on all sides, than it had before. And this power of rarefaction arising from the Heat, is the very same, as if that Air had been made so much denser in the degree of Heat in which it was before. The thing will be evident by an Experiment. For if in the case, and with the *Apparatus* last exhibited, the Air in the Vessel sustains the Mercury in the Barometer to 28 inches; then if the Air in this Vessel was made twice as dense, it would raise it up to 56, as the Experiments of Mr. *Boyle* demonstrate. But now if the former Air being still closely confined within the same Vessel, is by the application of Air made twice as rare as it was before, then would that Air, tho' the very same in quantity, but thus rarified, elevate the Mercury likewise to 56 inches. This is a truth, which the Thermometer and Barometer, being tried together, have, in every variation of the Experiment, most certainly evinced. And thus by the application of Fire to Air, there arise a great number of very surprizing chemical effects which could not be foreseen, which cannot be ascribed to any other cause, and which ought to be very accurately taken notice of.

Air rarified by Heat, acquires a greater elastic force.

* This is only true, when the Vessel which contains the Mercury is very large, with respect to the capacity of the Tube, the height to which the Mercury rises being always different, as the proportion betwixt those two is varied.

Fire rarifies
Air sooner
than it does
any other
Body.

This augmentation of space now, into which the Air, by means of Heat, expands itself on all sides, is effected by Fire sooner in the Air, than in any other Body, either Fluid or Solid, hitherto known in the Universe. In *Drebbelius's* Thermometer, an increase of Heat, not perceptible without such a contrivance, shews immediately a sensible rarefaction of the Air. But, indeed, the whole History of Fire already delivered, proves all these things so clearly, that there will be no need of the least repetition.

And to a
greater de-
gree.

It is evident from the same Experiments, that of all known Bodies, Air is the only one, which may be expanded by Fire to so great a degree. For Air, by the application of Fire, becomes so rare, that neither the measure, or limits of such its dilatation, has been yet discovered. The Heat of boiling Water expands the Air to a third part of its bulk. *Hist. de l'Acad. Roy. des Scien.* 1699. p. 101. In the Heat then which is capable of fusing Iron, certainly this expansion of the Air must be immensely great. But I refer you to what I have already delivered upon this head in the History of Fire.

Air of the
same density
is by the
same Heat
expanded to
the same de-
gree.

We find, likewise, that Air of unequal Masses, but the same density, is always expanded in the same measure by the same degree of Fire: So that these expansions in the same density of Air are, by a constant Law of Nature, always proportional to the augmentations of the applied Heat. Hence, therefore, if the expansion of Air of a given density, by a certain degree of Heat, is once discovered, it will constantly hold good in all similar cases. Upon this head let me refer you to some very curious Observations in the *Memoirs of the Royal Academy of Sciences*, 1699. p. 113. and likewise in the *Memoirs* for 1702, from the 1st Page to the 5th.

The more
the Air is
condensed,
the greater
elasticity it
acquires by
the same
degree of
Fire.

But with regard to the elasticity of the Air, this is likewise constantly observed, that the more it is condensed by pressure, the greater elastic force will it acquire by the same degree of Fire; and that nearly in a direct *Ratio* of the densities: Which very curious property, to the great advantage of Chemistry, was discovered by the very ingenious *Monsieur Des Amontons*. *Hist. de l'Acad. Roy. des Scien.* 1702, from the 1st Page to the 5th. *Mem.* 155. Hence, then, it follows, of consequence, that a portion of Air that is exceeding dense, may, by means of a very little Fire, acquire the greatest resisting force. If therefore it were possible, as I mentioned formerly, that common Air could in reality be condensed into a space eight hundred times less than what it naturally took up, then in such case, it might, by being acted upon by the Heat of boiling Water, sustain 29600 inches of Mercury; since common Air, by the same degree of Heat, will elevate it to 37: Which immense force certainly teaches us, that if the fiercest subterraneous Fire should, in the bowels of the Earth, be apply'd to Air reduced to $\frac{1}{800}$ part of its bulk, there would thence arise a most incredible power, vastly superiour to all the effects that we are acquainted with. This, however, at least, is certain, that if you increase the density of the Air, and at the same time augment the Heat that is applied to it, then the elastic Power of the Air will always be increased in a compound *Ratio* of both.

The more
rare the Air
is, the less
elastic force
it acquires by
the same de-
gree of Fire.

But on the other hand, now, the less the Air is compress'd, and so spontaneously rarer, the less is the elastic force that it acquires from the same degree of Heat. So that Air which by any means is render'd twice rarer, requires twice as much Heat to make it retain the same elasticity that it had before; and thus in any other degree of rarefaction.

These things the same celebrated Author, in the places last mentioned, has demonstrated

monstrated by the most correct Experiments. And hence we understand, that the Air in the highest regions of the Atmosphere, will scarcely acquire any increase of its elastic force from the most intense Heat, but on the contrary, will become here almost unactive, on account of its exceeding rarity; which answers, too, perfectly to Observation.

The last Law which we discover in the elasticity of Air, is, that it is contracted into a smaller space by Cold, as it is by an increase of Weights. Hence its density is always increased in proportion to the augmentation of the Cold. Since therefore the intensest degree of Cold in the northern parts of *Europe*, was discovered to be at O in the *Fahrenbeitian* Thermometer, hence by descending from the degree of Heat in boiling Water in this Instrument down to O, the effect of Cold in condensing Air was known likewise. And as since that, an artificial Cold has sunk the Spirit in the Thermometer to 40 degrees below O; the power of Cold on Air, in increasing its density, is now demonstrated. We discover, therefore, that there is not a Body in the World, the dimensions of which are more contracted by Cold, than the Air.

If we recapitulate now, what has been said, we find the sum of the matter to be this. If the Atmosphere being according to *Fahrenbeit's* Thermometer 46 degrees hot, has its Heat still farther increased by 166 degrees, it will then acquire a Heat of 212 degrees, which will make Water boil: But then the Air will become one third rarer, according to the Experiments of *Des Amontons*. A Heat therefore of 166 degrees, expands the Air one third. But now, if 40 degrees of Cold are added to 212, the sum 252 will be the distance between the greatest known Cold, and the Heat of boiling Water; within which distance, therefore, the Air is condensed to $\frac{4}{3}$, or about one half of the whole. If after the same method of computing, we suppose the greatest Heat of the Atmosphere, in the open Air, and from natural Causes, ever to have reached to 90 degrees, which I should think has been rarely observed; then it appears, that the rarity or density of the Air, from the sharpest natural Cold, to the intensest natural Heat, may be increased or diminished to $\frac{5}{3}$, or about $\frac{1}{3}$. And hence it is manifest, what alterations in Nature are brought about by the Air, considered only, as it is changed by natural Heat and Cold, whilst it surrounds and resides in Bodies; the knowledge of which, certainly, will hereafter be of the greatest use in accounting for fermentation, or putrefaction. The greatest distance, now, which *Mr. Boyle* discovered between the rarest and the most dense Air, he computed to be as 1 to 520,000.

In the last place, this elasticity of the Air is so proper to it, and inseparable from it, that it is not to be destroy'd by the intensest Heat; as appears by the following Experiment. Take a spherical Glass with a slender neck, put it into a Glass-house Furnace, and hold it to a part so hot, that it is just ready to melt, and in that Heat let it be hermetically sealed; then take it out, and suffer it to cool leisurely, and whilst it is yet whole and clos'd, immerse it in cold Water, and cautiously break off the top of the neck under the Water, and you will see the Water will be forced into the open neck with a very great *impetus*, and will fill the Glass, but with this limitation, that in the upper part of the belly of it, there will be some true elastic Air, thus evidently shewing, that the elasticity, by so intense a Heat, could not be destroy'd. And in this same Experiment, by weighing the Glass quite filled with Water,

Air is condensed by Cold.

How far

The elasticity of the Air not to be destroy'd by Fire.

and then weighing it again filled with Water and this Air together, we may discover the expansion of the Air in that Heat, in which Glass is ready to melt. Hence the Chemists might know what changes may be expected in their Operations, when Bodies full of Air are committed to so strong a Fire: Yet all these are things but rarely thought of, tho' it very much concerns Operators to have an Eye to them.

Nor any
other way.

In a word, since after the greatest rarefactions from 1 to 520,000, and upwards, and the like reciprocal condensations; after the application of the most piercing Cold, and the intensest Heat; after the greatest compressure and relaxation; and after the Experiments continued for so many years, as beforementioned, this elasticity remain'd perfect, and without diminution, we may very probably conclude, that the Air in this respect, is created such an Element, as by means of its immutable elasticity, and mobility, is constantly vigorous and active, undergoing as is were a perpetual ebullition and *subfultus*, penetrating into, and acting upon all Bodies, and keeping them in a continual agitation.

Of the con-
tents of the
Air.

After having, for the service of the chemical Art, considered the properties of Air, the order of our subject requires, that in the next place we should treat likewise of those Corpuscles which are blended and contained in the common Air. And these, in reality, are incredibly numerous, of various natures, and perfectly different in different parts of the Atmosphere. Rightly, therefore, to conceive of the Air, is to consider it as an universal Chaos, in which Corpuscles of almost every kind being confounded together, make a composition, consisting of the most different parts. 'Twill be our business to give you a particular account of them, that we may be able to make just conclusions concerning it.

In the first
place there is
Fire in it,
and under
what Law.

In the first place then, in the common Air, there is always and every where Fire. This has been shewn already in our History of Fire; where likewise it has been demonstrated, by every trial of the Thermometer, that Fire resides in the common Air, in the same manner, and in the same quantity, as it does in any other Body whatever. Nay farther, and it there exists, just in the same quantity as it does in the *Vacuum* of *Torricellius* or *Boyle*. This I learnt evidently from the Thermometer, by comparing one that was in an exhausted Receiver, with another that was in the common Air. And this Experiment I have repeated frequently, after different methods, but always with the same success. And hence I was fully convinced, that Fire of itself, and without any other cause intervening, exists in *Vacuo*, the Air, and every other kind of Body in the same quantity, and with the same activity; and that therefore this rule was again confirmed, that Fire is distributed as the spaces in the Universe. Hence, too, I discovered likewise, that after all the Air in the *Vacuum* of *Torricellius*, and almost all of it in that of Mr. *Boyle*, is extracted out of any space, Fire never then makes its way into that *Vacuum*, so as to fill up the space deprived of Air. For if this were the case, then there would of course arise a greater Heat from the accumulated Fire in this *Vacuum*; and consequently, a very sensible Thermometer, would give some indication of such increase: Or at least, you must be obliged to allow that there is Fire there, that is not capable of expanding Bodies, which to me is the same thing, as if you should say, that Fire is not Fire. Whatever, therefore, the Followers of *Descartes*, and others, have commented upon this subject, their reasonings have never been found

found to answer to any Experiment. And again, since Bodies that under the same surface contain the greatest quantity of corporeal mass, or the most dense of all, as Gold, and Spaces the most empty, as the *Vacuum* of *Torricellius*, of themselves possess perfectly the same degree of Heat, it follows very evidently, that neither Bodies, nor *Vacuums* have any power of attraction with regard to Fire. And as I have in a former Discourse proved, by undeniable arguments, that no one Body is naturally more attractive of Fire than another, it follows, that no part of the Air is more or less hot on account of its being replete with different kinds of Bodies. Fire, therefore, of itself is always very equally distributed through the Air, considered alone, and without the intervention of any other cause; nor are there in the Air any Magnets to Fire. In the mean time, however, an infinite number of causes may arise, and be applied to the Air, by means of which there may happen in the Air a collection of Fire, scarcely to be determined in any particular place. Of which matter I have treated already in our History of Fire, and shall have occasion to speak again hereafter.

In the second place, there is Water contained always in the Air, and in every part of it, and that in such a manner, that it does not appear that it can be wholly separated from it, by any contrivance whatsoever. Does there not a watery Vapour perspire continually from every healthy person? Does not *Sanctorius* compute, that in the space of one night and day there exhales from a man in health nearly the weight of 5 pounds, much the greatest part of which is Water? Consider then, I beseech you, what a vast quantity of aqueous Steams must be continually exhaling from the animals of all kinds, that are scattered all over the Earth; and that all plants, likewise, send forth a dewy, aqueous Vapour, is a thing that has been long confirmed by observation: But the very industrious and ingenious Dr. *Hales* has lately, in his curious treatise of *Vegetable Statics*, reduced the vast quantity of aqueous Vapours exhaling from Plants to computation. Why should I mention the Water, that by means of subterraneous, culinary, private, and chemical Fires, is continually forced up into the Air? What the incomparable *Halley* has delivered upon this head is sufficient. From the observations which he made with the greatest care, and accuracy, it has long been certain, that from the surface of the *Mediterranean* alone, in the space of a summer's day, there exhales by means only of the æstival Heat, without any assistance of Wind, 52,800,000,000 tuns of Water. See the *Phil. Transf.* Vol. II. p. 109. And the Wind and Sun raise up and disperse from the surface of that Sea, still a larger quantity, *id. ib.* pag. 110. and 111. if you compare now the quantity of Fog, Dew, Rain, Hoar Frost, Hail, Snow, and nocturnal Moisture, that may be collected in the space of a whole year, with the Water which in the same time, by means of the natural Heat, has exhaled into the Air, you will find, that in one year's time, there falls upon, and exhales from the Earth, about the height of thirty inches; as the very ingenious *Krunkius*, with the greatest labour has plainly proved in his Meteorological Tables. Hence it is very likely, that *cæteris paribus* there every year exhales into the Air, from the whole surface of the Earth, the value of thirty inches height of Water. And of consequence, since the *area* of the Earth's surface is sufficiently known, it is easy to compute the immense quantity of Water, that is always suspended in the Air.

And Water.

Which appears to the eye.

And that Water is contained in every portion of the Air, is continually evident to the eye in Mr. Boyle's Air-pump; for there, as the Air, by means of the action of the pump, becomes more and more rare, and less fit for the suspension of Water, the inside of the Glass becomes cloudy with a truly aqueous moisture; the very same Experiment thus evidently evincing, that Water does really reside in all parts of the Air, and that as the elasticity of the Air is diminished, it becomes less and less capable of retaining it.

And appears likewise in the augmented weight of a fixed Alkali.

But that there is a very large quantity of Water always, and every where dispersed through the Air, appears evidently to the eye in your dry, alkaline, fiery, fixed Salts; for if these, when they are perfectly pure, are exposed to the Air, they will spontaneously dissolve, by means of the Water which they attract out of it. But that you might have ocular proofs of this yourselves, I took, three days ago, at nine in the morning, two ounces and one drachm of Salt of Tartar, dried in such a Heat, that it melted in the crucible; so that there was no Water at all remaining in it. I then laid it into this glass basin, which was made very clean; and in this manner exposed it to the Air, this cold, dry weather, from the 17th of January to the 20th, in this place, which is pretty high, and very dry. And what now is the consequence? Why you see, upon examining it by the Scale, that it weighs three ounces four drachms and a half; and consequently, that it has gained an additional weight of one ounce three drachms and a half. Nay, if we thus examine this Salt by a pair of Assay-Scales, we find it is every moment gaining something in weight. And as there appears such an increment of weight, within the compass of three days, so if it is kept a considerable time in the Air, the whole of it generally dissolves into a liquor entirely fluid, pinguious, thick, somewhat tenacious, and unctuous, and that is almost three times heavier than the Salt first exposed; and this Liquor the Artists call Oil of Tartar *per Deliquium*, besides which, there will then remain at the bottom of the Basin, a very small quantity of a white Earth. If now, as has been done, you put this Liquor thus produced by the Salt and Air, into a glass Cucurbit, and with an alembic, which is a very tedious operation, you draw it to a dryness, there will then very pure elementary Water distill into the Receiver, and a dry Salt of Tartar, purer than it was before, and less ponderous, will remain at the bottom of the Cucurbit. This Salt, therefore, by being exposed to the Air, receives from it this large quantity of Water. And here we may observe, that the Water thus communicated to the Salt by the Air, dissolves it in a very different manner from what it would have been dissolved if pure fluid Water had been poured upon it; for this dilution in the Air, being slow and successive, by the application but of a very small quantity of Water at a time, dissolves only the pure alkalious Salts that are easiest of all dissolved, and therefore most nicely separates this part from the rest that is dissolved with more difficulty, that is, that is somewhat more terrestrial; which cannot be effected in any other manner. And hence it comes to pass, that by such a dissolution, and coagulation, this whole Salt is at length converted into an Earth, and a volatile principle, which disappears, and is scarcely perceptible afterwards. This *Van Helmont* knew very well, and other Alchemists had come to the knowledge of it long before him. In this Experiment, now, it appears to me particularly surprizing, that the very moment, as it were, that this Salt is taken out of the strongest Fire, and exposed to the Air, this humectation and dissolution, commence, and the increment of weight, perceptible

perceptible by the smaller balance, is begun, and from that instant, increases every moment. And this, which I have very often beheld with astonishment, has happened even while the Salt has continued exceeding hot, and been detained in a place too, which itself was very much heated by being near enough to the Fire; so that I could not, with the utmost care, keep off the Water of the Air from the Salt. And again, now the weather is so cold, and dry, that the height of the Barometer is twenty nine inches and a half, I set the Salt with this Balon in a place, walled on all sides with a very close timber covering over head, which is always close and still, and into which no Wind can enter, and you observe the effect is the same. But there is yet another thing more to be observed, in this wonderful attraction of Water from the Air into a dry alkaline Salt, which, some years ago, a good deal engaged my attention. I wanted a very acrid, dry, fixed, alkaline Salt, in order to demonstrate to some persons, who would not believe it, nay, who even denied the possibility of it, that there might be a Tincture produced in an instant from that Salt, and pure Alcohol; a truth, which some famous chemical Authors have in their writings proscribed as a fiction. This Salt, then, rightly prepared, glowing hot, and as yet in fusion, I poured into a very hot brass Mortar, and with a very hot brass Pistil, rubb'd it as fast as I possibly could, and as soon as ever it began to come to a consistence, I shut it up into a very hot and dry glass Bottle, and immediately stopping the mouth of it with a Cork, and a piece of Bladder softened with Oil, secured it as close as possible. And what do you think was the issue? Why when I came to try the Experiment, though I had frequently before met with success, yet the event at that time would not answer. Surprized at this, I carefully examined every circumstance, that might produce this variation, and discovered at last, that the surface of the Salt was a little moistened by the Air in the Bottle, and that therefore, this being already impregnated with Water, the Alcohol could not come immediately to it.

Now whilst I carefully consider these things, I am clearly convinced, that in so small a portion of Air as can be contained in a Bottle, which will hold but three pints of Water, there is Water enough to moisten an ounce of Salt of Tartar, and to increase its weight. And having repeated the Experiment with the same success, I learnt at the same time, that the Water contained in that portion of Air, which perhaps is 850 times heavier than the common Air, must of consequence make up the greatest part of the weight, which is statically discovered in the Air itself. For if one eight hundred and fiftieth part of the common Air was Water, then the whole weight of the Air would certainly be owing to the Water alone which floats about in it, and the other parts contained in the aerial Mass, would make nothing towards the weight of it; nay, would not, perhaps, gravitate at all. Upon which subject I had some conversation formerly with my good friend Mr. Henry Van Deventer, famous for his valuable writings on Midwifry, who told me, he had thought of the very same thing.

It makes the
greatest part
of the weight
of the Air.

Whoever now considers all these *Phænomena* with attention, must certainly hence infer one, two, or all three of the following propositions. Either, first, the Air, in all still, close, and subterraneous places, must be in a perpetual motion, that by this means it may apply that little quantity of Water, which is diffused.

A wonderful
property of
the Air.

diffused through its whole Mass, to the surface of the Salt of Tartar, so as to leave it there; for if a cubic foot of Air contains at the most $\frac{1}{4\frac{1}{2}}$ of a pound Troy weight of Water, and communicates, within a Vessel close stoppt, this Water to the Salt, then it follows, that all that Air must so revolve about the surface of the Salt, as that all its parts may successively come in contact with it, and thus deposite the Water they contain: Or else, secondly, we must conceive, that those Particles of Water, which at one time are dispersed throughout the whole mass of Air, are at another time so moved through that Mass, as that they are perpetually and successively now in one part of the aerial Space, and now in another, till at length they all happen to meet with that Salt which is placed within it: Or, in the third place, we must acknowledge, that there is a true attractive power between a fiery, fixed Alkali, and Water, so that like two Magnets, they reciprocally attract one another, in the same manner, as we read in *Sendivogius* of an Alkali of the Earth, that attracts the celestial Dew, in order to a fertile impregnation. Whoever, now, prefers this last way of thinking, must perceive, at the same time, that this attractive power between the Water of the Air and an alkaline Salt, must extend to a considerable distance, since a very little of the Salt will grow four times as heavy as it was at first, by means of the attracted Water; for an ounce of Salt of Tartar, whilst it is converted into 4 ounces of Oil of Tartar *per Deliquium*, must have drawn into it 3 ounces of Water. But 3 ounces of Water require at least two cubic feet and a half of Air to be diffused through in order to be attracted into that one ounce of Salt; which Space, with respect to that one ounce of Salt, is certainly exceeding great. But from all kinds of Experiments, it appears very probable, that all these three causes concur, at the same time, to the production of the same effect.

The elastic quality of the Air don't unite with an Alkali.

But nothing appears to me more extraordinary in this affair, than that whilst the Water is drawn into the Alkali from the Air, and thus makes Oil of Tartar *per Deliquium*, which in weight is to Water, as 7 to 5, but to Air, as 1190 to 1: I say, that whilst the Oil of Tartar *per Deliquium* is thus produced, there should be found in it nothing at all of the aerial Elasticity; so that this Alkali thus separates the Water from elastic Air, and unites it to itself, but rejects intirely the aerial elastic Quality. Hence, therefore, again it appears, that Air, free from Water, is very elastic; but on the contrary, when it is replete with watery Vapours, it proportionably loses somewhat of its proper Elasticity; and again, that by means of a great quantity of fixed alkaline Salt produced on the Earth, a vast deal of Water may be drawn out of the Air.

At what time there is the most Water in the Air.

In a continuance of serene, and very dry weather, the Air becomes always more ponderous, the Atmosphere heavier, and the Water mounts higher in the Air. So that in reality there is never more Water in the Atmosphere than at that time, when by reason of the dryness here below, people generally imagine there is the least of all: But the Water, then, is far more widely distributed, and dispersed; for you easily apprehend, Gentlemen, that the higher from the Earth the Water ascends in the Atmosphere, the greater are the Spaces into which it is diffused, and the farther, consequently, its Particles recede from each other; and that then they exist separately, and do not immediately unite, nor afford any moisture. But if the Barometer is very high, and at the same time, thick and stinking Fogs appear, then do the watery Particles almost

almost always float below along with gross, unctuous, and saline exhalations; all which, at that time, will not, in an exact mixture, be equally distributed or united. But again, when the Barometer is very low, and the weather at the same time is very hot, and very cloudy, then the Water comes down to the lower regions, but in an uniform Vapour, very moistning, but not yet producing Rain. From these observations it is manifest, that the Air, when loaded with abundance of Water, often appears very dry, bright, and perfectly clear; and that on the other hand, when there is less Water in it, it may, by the descent, collection, and unequal distribution of the Water, appear cloudy, dark, and very moist. And this is demonstrated evidently in Cucurbits, Alembics, and Glass Receivers, whilst Water is distilling in them: For if the Vessels are kept stoppt very close, whilst a distillation is going forward, all appears bright and clear, and no such thing as a cloudy Vapour is seen; but as soon as ever the Water in the Cucurbit, upon the removal of the Alembic, begins to exhale freely into the Air, the whole appears covered with watery, and very thick Vapours, the equable compressure being now destroyed.

But if in the summer season, when the weather is fair and very dry, and the surface of the Earth has been for a considerable time parched with a great Heat of the Sun, then not only the watery, but other Particles likewise less volatile, as the oily, and saline, are by the power of the solar rays carried up into the Air, and fill that part of it which lies nearest to the surface of the Earth. And so long as these exhalations are kept in agitation by the Heat of the Sun, so long nothing of them appears to the eye: But as soon as the solar Heat, which at three in the afternoon is the greatest, begins to remit, the Air not long after begins to grow cool, tho' the Earth, which retains the Heat communicated to it by the Sun a thousand times longer than the Air, being yet hot, continues to exhale the agitated Corpuscles; by which means there is collected a white, dense Vapour, which is cool above, but still continues warm below. This Vapour, therefore, appears first in ditches, and watery or marshy places, whence dispersing itself by degrees, it covers the face of the Earth in the evening, and night time, with a cloud consisting of this kind of Particles, which in the morning is again dissipated by the Heat of the rising Sun. And this is what we usually call Dew; which appears, from what is here said of its production, to be a very compounded liquid; so that nothing useful can be asserted concerning its proper nature, which would in every circumstance hold true. For since it is a composition of all the Corpuscles of the Earth, which are rendered volatile by the æstival solar Heat, exhaling and descending again, and blended and confounded together, it must doubtless appear, upon the least consideration, to be a perfect Chaos. Nay, and in every particular part of the Earth, it must be likewise of a quite different kind, according to the various nature of the Bodies in the place where it is produced. In gravel-pits, for instance, and in high, dry, heathy grounds of a large extent, there is collected but a very small quantity of this Vapour, and that almost intirely watery; whilst that which is collected about standing Waters, Fens, Marshes, and fat bituminous grounds abounding with putrified fish, and other animals, is perfectly of a different nature, and very often pernicious to mankind. It is no wonder, therefore, that the Chemists, in the artificial resolution of Dew, have met with such contrary principles, and written so differently upon the sub-

ject, that you can scarcely find two of them that give the same account of it. And as for those who expect to find the Spirit of Life, the universal *Menstruum*, the Mercury of the Philosophers, and the Niere and Steel of *Sendivogius* in Dew, they certainly scarcely seem to have read the works of these Philosophers to any valuable purpose. That this however is a very sharp, saponaceous, pinguious Liquid, abounding with a good deal of nourishment for Vegetables, I do not go about to deny. A Dew too collected in a certain part of the Earth, has yielded by distillation a Liquor that impressed upon Glass the lively colours of the Rainbow, which could neither be removed by friction, an alealine *Lixivium*, or *Aqua Fortis*: And this Liquor was inflammable, like Spirit of Wine; as appears from the chemical Experiments related in the *Republick of Letters*, Tom. I. p. 590. And again, distilled Dew, digested for the space of eight days in a gentle Heat, and by repeated distillation rendered six times more subtil, is said to have broke three glass Vessels, and to have remained perfectly insipid; tho' it was so very thin, that it resembled pure Spirit. *ibid.* 1708. p. 152. And farther, in the *British Observations*, Dew is described as being like Butter, of a yellowish white colour, soft, melting by being rubb'd upon the hand, and growing dry and hardning by a moderate Heat, of a very fetid smell, in the Winter, and in the Spring, particularly, produced in the night time, in pretty large Lumps. *Philosoph. Transact. Abridg.* Tom. II. p. 143. But the nature of Dew is likewise surprizingly various, according to the different disposition of the weather, and according to the various and successive changes of the meteors in the Air; for hence it comes to pass, that the very minute Seeds of small Plants, and the invisible Eggs of the smallest *Animalcula* are mixed with it, together with an infinite number of other things; which being all digested, fermented, putrified, and distilled together, yield at different times principles of very different natures, and hence lead the Chemists into very extraordinary opinions. See *Abridg. Philosoph. Transact.* Tom. I. p. 141. The principal part therefore of Dew is Water; the rest, on account of their manifold variety, cannot possibly be described.

The Clouds.

That the Clouds are produced in the Air, from almost Water alone, there is scarce any one that doubts. But Water every where equally disposed, is transparent. Clouds, therefore, are collected from what is beginning to be Water, but the parts of which, in the mean time, are circumvolved among one another with an unequal motion, neither resting nor moving equably; as I just now hinted. If the Water that is floating about in the Air, now, mounts higher and higher, its particles at length arrive in places so far above the Earth, that they are not any longer much united together, but receding from each other, they do not then constitute Water, but only the elements of it. But when these Elements of Water come to descend again from those upper regions, and are contracted into smaller Spaces, where they associate together, and become a kind of Water, they then form Clouds. The higher, therefore, the Water ascends in the Air, the serener and dryer the weather will be, and the freer from Clouds; and the contrary. But Water is carried up to a very considerable height in the Air; for in *Carniola* in the neighbourhood of *Venice*, there are mountains 10274 geometrical feet high, on the tops of which there are indications of moisture. *Act. Lips.* 1689. p. 552. And on the highest tops of those Mountains, Nature presents to our view perpetual Snows; a certain Proof of the elevation of Water to such heights. Nay, and over the Mountain *Teneriff*, the

the highest in *Europe*, there constantly about noon hang Fogs, or little white Clouds, which are daily resolved into Water, which flows in such plenty down the mountains, that it supplies the place of Showers, and waters the whole Island, without Rain, *Aët. Lips.* 1691. p. 98. We are certain, therefore, that Water ascends to such a height. But had we sufficient observations to confirm the account *Maignan* of *Toulouse* gives, in his treatise of *Perspective*, p. 93. of the wonderful *Phænomenon*, which he says he had observed, the ascent of the Water in the Atmosphere would be found to be abundantly higher: For he tells us, that in a very clear night, and that at midnight too, there appeared in the month of *August*, an exceeding bright little Cloud, which spread itself almost as far as the Zenith, or vertical part of the Heavens; and says, that *Riccius* observed the same thing, in the neighbourhood of *Rome*; and from these Observations he infers, that Clouds may be elevated beyond the projection of the Earth's Shadow. But this projection, now, if astronomically computed from the given time and place of the appearing Cloud, would give a prodigious distance from the Earth; and hence, perhaps, that appearance was rather to be ascribed to some other unknown cause, residing in the upper regions of the Air, and exceedingly lucid, since on the tops of the highest mountains, there are rarely observed any Clouds, but on the contrary, to a spectator placed there, they appear below him, towards the Plain.

The lower Air being full of Water, begins to unite the Elements of Water closer together, and by this association to form very little drops, which falling down, produce a small Rain, for the most part thick, but descending with no great force. For the less these drops are, the greater surface they contain, in respect of their quantity of Water, and consequently are the less able to descend swiftly through the resisting Air. Small Rain.

But when the Water in the upper regions of the Atmosphere is collected together, and thereupon becomes heavier, and begins to descend; then, by gradually coming down into smaller spaces, it continually unites to it the other Particles of Water which it meets with in its fall. By this means, therefore, are produced those very large drops which in *Europe* have been observed to have been three lines in diameter, but among the *Negroes*, a whole inch, *Aët. Lips. Suppl.* 1. 425.; which Drops containing a great weight of Water under a less Surface, rush more violently through the Air, and fall to the Earth with a mighty impetus. The higher, now, the place is from which they fall, the larger the Drops are, and so *vice versa*; for it has been always observed, that the Rain, in the upper part of a high mountain, is the smallest, but that, as you gradually descend, it forms larger and larger Drops, till at the foot of the Mountain it produces the largest of all. Hence it comes to pass, that the hardest Showers happen in Summer, when the Water, being driven rapidly downwards on a sudden, cause thunders, lightnings, and tempests. And hence, likewise, the Drops of the Showers, in Summer time, are usually larger than they are in Winter. Lastly, observation has made it very certain, that Rain, in every part of the Atmosphere, is there the smallest, where it is first produced. Great Show-
ers.

But now when the Air, abounding with Water, and waxing cold in the night time, is carried against the upper parts of high mountains, especially if they are disposed in a long range, then this cold and dense mass of Bodies, particu- Springs.

larly towards the North and East, during the first part of the night, and towards the South and West after midnight, stops, cools, and unites this Water of the Air, and converts it into a watery humour, which gives rise to a great many little *striae* of Water, which in the highest part of the mountain are small, but as they descend, and are joined with one another, become larger, and by this means produce a perpetual trickling down the mountain, and afford an incredible quantity of Water, which runs down, and produces various rivulets, according to the various channels of the mountain, or the land about it; and when these by subterraneous passages descend from a high part of the mountain to any part of the declivities, and there burst through outlets, and so discharge their stream, they then yield a pure Water, either falling right down, or bubbling up from a spring. And here it is very easy to conceive, that, according to the different height of the springs, in respect to the outlets, the playing of the fountains must be various. And hence, likewise, it is easy to account for the variety of springs, both in the quantity of Water, and every other circumstance. And hence again it appears farther, how it comes to pass, that there are no springs, but where there are pretty high mountains, and that wheresoever these are, there likewise are observed springs: The truth of which appears no where with more evidence and beauty, than in the fortunate valley of *Cassimire*, mentioned by *Bernier*, in his *Description of the Empire of the Great Mogul*.

Brooks, Rivulets, and Rivers.

Again, wheresoever there are such Mountains, and Springs, there the Water, after running down from the Mountains, or perpetually bubbling up from the Springs, is discharged into Rills or little Currents, continually flowing, but for the most part with a gentle course at their heads. When afterwards different currents join their courses together, the stream becomes stronger, and being continually augmented by Rivulets which discharge themselves into it, in a short time produces a River. This again, not long after, being still as it passes augmented in strength and quantity by the accession of other streams, forms a River still flowing with a more rapid course, always tending from the higher to the lower ground, and at length discharging itself into the Sea, from which it never returns again; whose contents, however, in the whole, are by this means never increased, inasmuch as what it receives by the discharge of the Rivers into it, it gives up again continually by exhalation. Sometimes it happens likewise, that the rapid torrents of Rivers sink down into passages under the Earth, disappear, and rise up again in some other place. Hence it comes to pass, that in flat countries, where there are no Mountains, or Springs, there are never formed any Rivers. And for this reason, the supreme Wisdom has thus distributed Mountains throughout the whole Earth, that they might be beneficial to mankind, by producing these collections of Water. And hence, lastly, all the World over, the courses of Rivers answer the order or rangings of the Mountains. Upon this subject, let me refer you to the discoveries of the incomparable *Halley*, in the *British Philosophical Transactions*, which he truly has a right to the merit of. All these things now, it concerns us to be particularly acquainted with, who are prosecuting the study of the chemical Art, in which there is almost a perpetual necessity of considering the variety of the qualities of Air and Water. And these Observations will likewise be of singular use in our following Treatise of Water.

By

By all that has been hitherto said, however, it does not appear certainly, how great the utmost height is, to which Water can ascend in the Atmosphere: But this, at least, in the mean time, we are absolutely sure of, that on the top of the highest Mountain on Earth, there never is any Air without some Water in it, since the top is always found moistened with humid Vapours. And hence it is evident, likewise, that it is not possible, by any manner of Art, to make use of Air in our chemical Operations, in which there is not contained Water. Perhaps, indeed, from a given quantity of Air pent up very close in a dry glass Vessel, all the Water may be drawn out: For if some Salt of Tartar, coming as hot as possible from the Fire, is reduced to a fine Powder, and thrown very dry into this glass Vessel, and the mouth of it is immediately stopp'd close; then this exceeding dry Alkali will attract into it all the Water that is contained in the included Air: But then, no-body can apply this Air to any chemical Operations; because as soon as ever the Vessel is opened, this dry portion of Air mingles again with the common Air, and is immediately moistened by the Water which that was filled with.

There is every where Water in the Air.

Water separable from the Air chemically.

But farther, we are assured from undeniable Observations, that the higher the Water is carried into the Air, the farther it disunites its parts, disperses them through wider and emptier spaces, and at the same time grows colder. For upon examination it has been constantly found, that in every part of the habitable World, the Heat *cæteris paribus* is greatest at the Surface of the Earth; and that at the very summits of the highest Mountains, a freezing cold preserves a perpetual Snow. This is true, even at the Equator and in the Torrid Zones: So that there is not in the hottest part of the Earth a Mountain very high, whose top is not exceeding cold. Nay, and the cold increases gradually, as you ascend from the foot to the summit of the Mountain, in such a manner, that the increment of Cold is always proportional to the increase of height. This is an Observation that will always hold true, if all other circumstances are alike. When Water, therefore, ascends to such a height in the Air, that it meets with a freezing Cold, it must necessarily be congealed into Ice, unless its Elements are so separated, that none of them touch one another; for so long as the Particles of Water are there dispersed from one another, so long there will be no appearance of Ice: But as soon as ever in this high and cold region of the Air, these Elements begin to come into mutual contact, then they begin likewise immediately to be congealed into little icy Globules, which float up and down through the clear Air, and falling upon the Surfaces of the Bodies they meet with in that region, produce a very fine hoar Frost, but otherwise are scarcely perceptible. In the Atmosphere, therefore, there is an Orbit concentrick to the Earth, in which the Water of the Air, when it is carried up to that height, is always frozen if it is united together. And the higher it is elevated above this Orbit, so much the sooner and harder it will be frozen. But at the same time, however, it is not improbable, that when the Water arrives to such a height, its Particles will be so much the less united, and therefore, will rarely be congealed, but on the contrary will float about separately, 'till some other cause shall happen to unite them together, and by this means form them into Ice.

Water in the highest places becomes Ice, or ceases to be Water.

When the Water, therefore, in the Orbit just mentioned, is congealed, then by an adunation of a greater weight of Water under a less Surface, it must

Hence Snow.

likewise immediately become heavier, by which means, it will of consequence begin to fall downwards, and thus descending into spaces that are smaller, and are more replete with Water, will associate to itself other watery Particles, and so gradually form larger icy concretions, which will now put on the appearance of Snow, or small Hail. But as there may be a great number of causes, and those perfectly different ones too, by means of which, the Elements of Water, that were before scattered in the upper Air, may on a sudden, and in a very large quantity, be brought into contact with one another in the icy region of the Atmosphere; hence you easily apprehend, that considerable pieces of Ice may in a pretty short time be there produced.

And Hail.

But these icy Bodies may in like manner be collected together; and when this happens, there will appear little Clouds, high in the Air, and white by means of the reflection of the Sun, which suddenly falling downwards with a mighty velocity, seem to increase very fast in their magnitude, and rushing from on high upon other like Clouds, by that collision produce Thunder, Lightnings, Tempests, showers of Rain and Hail, which are always the more violent, the higher the place is from which they fall. And hence it comes to pass, that in Summer time, when the Weather has been long clear, the lower Air very dry, the Atmosphere heavy, and the Water therefore in it carried up to a very great height; then the Atmosphere being on a sudden rendered lighter, there usually very soon follow the *Phænomena* we have just mentioned, especially between the Tropicks, where, if a little white Cloud appears very high in the Air, it is a sign that a terrible Storm is just at hand. And it is exceeding probable, that the Hail, which is always formed in the upper and colder regions of the Air, as it descends by its weight into the inferiour and warmer ones, is there dissolved by the Heat, and produces those great showers of Rain, which accompany, follow, and put an end to Thunder and Lightnings. But if the Hail happens to be so swiftly brought down through the Air, as that by reason of its quick descent it cannot be melted, it then falls to the Earth in form of icy Stones, which often, by their size, weight, and motion, do a great deal of mischief. In the Abridgment of the *Philosophical Transactions*, N. II. p. 144. we have an account of some of these that weighed a full pound.

Thunder
and Light-
ning.

This certainly we are assured of by Observation, that Clouds of a very white colour, to which there presently succeeds a pitchy blackness, terrible Thunder, Lightning, and Tempests, are always accompanied with Hail. And hence I imagine, you will be more ready to believe, that the causes here assigned for these *Phænomena*, are the true ones, than to come into the opinion of Dr. Hook, concerning the concretion of Hail in the course of its descent; which you may see in his Posthumous Works, in the Life of the Author, p. 24. And hence it may likewise be questioned, whether, for producing even the greatest Thunders, and Lightnings, Nitre and Sulphur are always necessary; since the very violent collision of hard Ice suffices, perhaps, for the striking out a vast quantity of Fire; doubtless, it is sufficient for producing the loud peals and rumblings of Thunder. Especially, if we likewise consider, that the Fire of the Sun, by its heat, reflexion, and refraction, can act in infinitely different ways, upon the aqueous congealed Matter, we are here speaking of. If this then be taken into the consideration, what variety of Colours, what diversity of Figures, and what difference of Dimensions may we not suppose to happen in this aerial Ice?

But

But amongst the principal causes that are concerned in the production of such extraordinary and various *Phænomena* so suddenly produced in the Air, which before was calm and serene, we have a particular regard to the diminution of the weight of the Atmosphere. For the Water always begins spontaneously to separate itself from the Air, when it becomes lighter, and thus discovers itself, tho' before it did not appear. In the next place we imagine, that the Bodies of Air which are driven from opposite quarters, often strike against one another, and by this collision, very quickly unite together the Elements of Water, which before were floating about separately. Something likewise may perhaps be owing here to the various Aspects of the Planets; not to mention the efficacy of the Winds, and the vicissitudes of Heat and Cold towards these productions. Every one of which separately, or all of them together, may easily enough bring about the effects we have mentioned, with many others.

The Cause
of these pro-
ductions.

On the other hand, now, if we have a mind to turn our Eyes to the causes which mingle Water with the Air, and carry it up into it, we shall find there are a great many. The principal, however, of these, is the Sun, the direction of whose Rays upon the Water, the nearer they approach to a perpendicular one, the more Water they always carry up into the Air. Upon which head consult the Observations of Dr. *Halley*, which I have already cited in their proper place. Another cause wonderfully assisting the foregoing, is the subterraneous Fire, which is always in action, never at rest. For it has been evinced by Observations, that in Mines sunk lowest, or in the deepest Wells, you first come to a depth in which Water never freezes, but which continues almost always of the same Heat, without any alteration; as the celebrated Academy at *Paris* observed long ago in the Well of their Observatory; but that as you descend lower, the Heat begins to grow greater, increasing gradually more and more, in proportion to the depth, till at length it becomes so suffocating, that unless it be tempered by the coolness of running Water, and the Air that is thence produced, it overcomes the Miners. And we see likewise, that in Winter time, when the Water is covered with Ice, and the Earth with its hard frozen Crust, if the Ice is broke, or the Earth is opened, both the Water and the Earth smoke with heat. Nor had the Philosophers, whom I have formerly heard discoursing on this subject, any grounds for asserting that this was all a fiction, and that it was impossible that Fire should thus exist in the bosom of the Earth, because it can neither be supplied with a proper *Pabulum*, or be agitated by Air: For certainly we ought to consider, that by the sole attrition of the condensed Air, in the bowels of the Earth, this Fire may be produced and preserved without any other Air or any *Pabulum*. For should the Air at any vast depths under Ground be condensed six hundred times more than the common Air, what effects wou'd it not be capable of producing? Incredible ones without dispute, since Authors worthy of credit have declared, that Air, forcibly compressed in an iron Tube, has grown warm there. It is not to be question'd, therefore, but that, in the deepest parts of the Earth, where the Bodies are compress'd by the prodigious weight of those which lie above them, the smallest attrition must produce the greatest Heat. And hence as the action of this Fire is perpetual, so likewise must be the effect of it too, viz. a continual exhalation of Water. In the third place, we have regard to the very great

Causes that
carry Water
up in the
Air.

great and constantly repeated effects of the common Fires, made use of by Mankind in every part of the inhabited World, in the dissipation of Water, whether alone, or contained in Animals, Vegetables, or Fossils. For doubtless, if any one computes the measure of this exhaling Water, which such Fire carries up and distributes through the Air, he will find it to be incredibly great. Again, in the fourth place, the force of a very sharp Frost carries off from Ice every moment a surprizing quantity, so that in a little time the Mass is consumed, being dispersed into the Air by the cold alone; as the excellent Mr. Boyle plainly discovered by an Experiment examined by the Ballance. But daily Observation likewise certainly evinces, that by the piercing Cold of a very severe Winter, all kind of Bodies are strangely worn away, diminished, consumed, and dispersed through the Air. In the fifth place, it seems probable also, that every physical cause, which is capable of so disuniting the Particles of Water from one another, as to make every one of them exist separately, will also by this means effect, that those Particles will immediately acquire so large a Surface in respect of their very small weight, that they will be able to float about in the Air. And indeed, this solution of Bodies into their smallest parts, appears at length so to increase their Surfaces in respect of their quantity of Matter, that in every division of them, this aptitude to swim in a lighter Liquid is very much augmented, as the Geometricians have long ago observed. But it is farther discovered by physical Observations, that besides the gravity of Bodies, there is likewise a certain repelling force, which tends to prevent the contact of the Surfaces of different Bodies, and which consequently, is always increased in proportion to the augmentation of their Surfaces. Hence therefore it follows, that Bodies very minutely divided, descend on this account with more difficulty by the force of their gravity, than they would do, if they were acted upon by the Law of Gravitation alone. And the action of this second property of Bodies seems particularly to prevent the continual and immediate descent of all the Particles of Water out of the Air that is about the Earth. Sixthly, it seems to be the effect of the very same property, that the Particles of Water may be expanded round the Air contained in them, and thus form that spherical Body which we call a Bubble. And besides, any other Heat, or expanding Spirit whatever, while perhaps it performs the same thing, may, as well as Air, be always at length capable of rendering Water lighter: But when afterwards the Water, being so divided into very light spherical Bubbles, is carried upwards, then does every Bubble expand itself more and more continually, and so is able to ascend for a long time, and to keep aloft in the Atmosphere. And hence it is manifest, that the Particles of Water may ascend to a great height. See *Halley* in the *Philosophical Transactions*, 1692. N. 192. p. 468, &c. But in the seventh and last place, there is no cause whatever which carries up such a quantity of Water from the Earth into the Air, as the Wind; as the same admirable *Halley* has elegantly demonstrated, and as I myself have learned from various Experiments, not without astonishment; for having exposed a copper Cylinder full of Water to the Wind in stormy Weather, I was surprized at the incredible quantity of Water carried off in a little time; whereas when the Wind was down, which happened presently after, but a very little Water exhaled, tho' the heat of the Weather was still the same. For this reason it seems ordered, that pretty high Winds should follow large quantities of

of Rain; that by thus agitating the fallen Water, and carrying it up again into the Air, they may prevent its stagnating and putrifying, and by this means proving destructive to the vegetable kingdom. All these causes, therefore, when they conspire together, are sufficiently capable of dissipating Water into the Air, and there keeping it in continual motion.

If we consider, now, the action of this elastic Air, replete with Water, upon the body of a Man, Fossil, or Vegetable, we shall find it brings about very many, and very wonderful changes. For if we reflect upon its particular fineness, by means of which it is exceeding penetrating, and is perpetually insinuating itself into every little space; and if at the same time we take into consideration its constant mobility, by which 'tis always kept vigorous and active, it is manifest, that these qualities being determined upon Bodies by the force of Gravity, are capable of producing an infinite number of effects. But the Water that is distributed through the Air, will likewise be still more efficacious, being itself agitated by the motion of the Air; and by this means it will more readily dissolve the Salts, and the saline and saponaceous Substances of the Bodies it is applied to. And as there are very many such parts in most Bodies, and those parts too are the principal instruments of their action; hence you very easily apprehend, that by means of the application of the Air, the proper virtues of Bodies may be excited, as far as they depend upon their peculiar Salts, and *Sapo's*: But these virtues, as we observed just now, are often their principal ones. In the mean time, however, the chief alteration induced upon Bodies by the Water of the Air, is its rendering fixed Salts, and other compound Bodies, volatile. This *Phænomenon* was observed by all the chemists of old, and is constantly found to hold true: That is to say, all native Salts, if they are rendered exceeding dry by an open Fire, and then pounded and exposed to the Air in a Glass Bason, will there, by means of the Water in the Air, be converted into a Liquid; and from the perfectly saline part there will be separated an Earth, which did not appear before. If this saline Liquor, then, thus freed from this Earth, is again thoroughly dried by a large and clear Fire, and afterwards the Salt beaten, and again dissolved in the Air, it will afresh deposite some earthy *Fæces*. And if by several repetitions of this solution, and inspissation, you thus remove all the earth that is every time produced, you will at length procure an incredible quantity; but at the same time you will have nothing else remaining; for that other principle, which before, in conjunction with the Earth constituted the Salt, is by this repeated action of the Water of the Air so disengaged from its earth with which it was incorporated, that now, existing separately, it becomes perfectly volatile, is dissipated into the Air, nor does ever again come within the cognisance of our senses. Nor has the industry of the Chemists discovered this wonderful *Metamorphosis* in native Salts alone, but likewise in the fixed Salts prepared by Fire from Vegetables; for by this tedious operation, these Salts are likewise resolved into an Earth, which serves to fix them, and a Principle perfectly volatile, which is intimately united with it. And these resolutions which are really very singular and wonderful, can be performed by no other means than this very subtil application alone of the Water distributed in the Air, which Art, formerly held a secret, being now more put in practice, has let abundance of light into the Chemical Art; though at the same time it has often too proved of disservice to the Chemical Artists,

Artists, who being quite tired out with the tediousness of the work, have lost in the end both their labour and the thing they were in search of. But again, whenever the Air abounds with Water, and is at the same time agitated by Heat or Wind, then this Water will relax the parts of Bodies so suddenly and so efficaciously as must surprize every one who is not acquainted with these things. But by this means, likewise, very many bodies are macerated; and others are thrown into fermentation. And as for the putrefaction of Bodies certainly, it is scarcely more promoted by any other cause than the humidity of a hot Air, which in a very little time resolves the Bodies, which are that way disposed, into a putrid, sanious matter. And for this reason the Physicians long ago asserted, that the plague itself is generated among Animals, from an Air that has been both very moist and warm, for a considerable time. In short, therefore, since it so dissolves Salts, and saponaceous and saline Substances, carries up all together, disperses them about, drives them against, and makes them penetrate into the Bodies they meet with, it is manifest, that by this means it must apply the particular forces of some Bodies to others, and thus brings about such actions between Bodies, as hardly ever happen from other causes. For what else appears by the fetid butter-like Dew, described in the *Abridgment of the British Transactions*, Tom. II. 141; or what else by the Salt Rain, observed at Sea? *Journal des Scav.* 1683. 435.

Other corpuscles in the Air.

Thus far then, Gentlemen, we have sufficiently considered the Air, with respect to its Elasticity, and the Fire and Water contained in it. We are now to regard it in another view. Let us then carefully inquire what other Corpuscles, besides those we have examined, float up and down perpetually in this Air. But this is a field of inquiry which has hardly any bounds: For as the Earth, considered in its whole extent, receives every thing that falls out of the Air; so on the other hand, the Air receives every thing again from the Earth; and thus between these two elements, there happens, as it were, a perpetual revolution and distillation of all things.

The native Spirits of Vegetables.

In the first place, then, all the parts that we can observe in Vegetables, are continually changing, and dispersed throughout the Atmosphere. That the Spirits of Vegetables do always, and every where exhale and fill the Air with a continual fragrance, there is none of you to be sure makes the least question. And that the Scents scattered through vast tracts of the Ocean from odoriferous Plants, inform the Mariners, before they discover Land, of their approach to the Shore, you are as well apprised of. And you know, likewise, that these Spirits spontaneously exhale out of the Bodies, in which they are generated, and are scarcely to be confined and preserved, except in Vessels stoppt very close. Hence, then, it follows, that whatever odoriferous Spirits are at any time by Nature produced in Plants, all these are, certainly, at length, contained in the Air alone. And for this reason it is not at all to be wondered, that these Spirits should afterwards return with the Water of the Air, into the Bodies destin'd to receive them, and that the Air should thus yield up to the Earth what it had first received from it. In reality, we find nothing in Nature less imitable by Art, than the fragrant Spirits peculiar to each Plant, which we have in a foregoing passage called the *spiritus rectores*: But these, when they are once freed from the tenacity of the Sulphur that entangles and retains them, always, from their own proper nature become volatile, and are dispersed through the Atmosphere.

Atmosphere. How various, then, and how beautiful must be the Effects that are hence produced? And how wonderful must be the grand *Metempsychosis* or transmigration that is by this means brought about?

But again, when we consider, that Vegetables, duly prepared by a proper fermentation, yield a vast quantity of vinous spirits, that are almost immutable, and of themselves continually exhaling; must we not hence conceive, that all those Spirits which have ever been produced from any fermented Vegetable whatever, over the whole Face of the Earth, have at length exhaled into the Air? And in this view we now look upon this Air again as a Cloud, as it were, of Spirits of Wine. In reality, whether Wine be drank by Men, or any other Animals, be outwardly apply'd by way of fomentation, or made use of either in Cookery, or Physick, certainly all its Spirits must sooner or later exhale into the Air, there remain for some space of time, and thence, at a convenient season, return to the Earth again. What wonder, therefore, if fermentation, which is the productive cause of Wine, should never produce Wine, without the free admission of the external Air. Does it not, possibly, return back again to Places and Bodies the Spirits which it had before drawn up, and for this reason must be always called in to our assistance, when they are to be generated again?

The fermented Spirits of Vegetables.

And finally, all those parts of Vegetables, which the Fire divides into exceeding minute Corpuscles, and converts into a volatile Vapour, the Chemists have likewise called Spirits; but these are likewise intirely carried up into the Air, and are continually floating about in it. As the Water of Vegetables, therefore, so likewise all these kinds of Spirits are perpetually tending upwards.

And those that are produced by Fire.

But farther, it is certain, that the proper native Oils of Vegetables, do by time, and the natural heat of the Air, at length intirely evaporate; and that whether they reside in compound Bodies; or spontaneously sweat out; or are forced out by pressure. For in reality, there are but few sorts of Wood, in which their Oils are so united with their proper Earth, that they are able to remain for ages together in the open Air. And as for the Oils of Vegetables, which Chemistry draws from them by Fire, whether this be done with Water, or dry, these are far more volatile, and sooner fly off. Thus, then, they form pinguious exhalations in the Atmosphere, which are very well disposed both to take Fire, and to support it. For as these oleaginous Particles are now so minutely divided, that they nearly resemble Alcohol while they float in the Air, being first heated by the attrition of the Clouds, they may be excited into a Flame by the dioptrical or catoptrical Fire, which I have already demonstrated may be produced in the Air. All these Oils, therefore, which ever were in Vegetables; a very few perhaps excepted, are dispersed into the aerial Chaos; whence, as Water and Spirits do, they return in their time, impregnate the Earth with a pinguious moistening Dew, and by thus circulating backwards and forwards, bring perpetually fresh prolific Supplies, and being deposited for a short time, return into the Air again. All this, now, happens chiefly in very hot weather. For if a long Drought, with a very great Heat, has carried upwards both the Water, and the pinguious Corpuscles of the Earth, then the first Fires that happen aloft with Thunder and Lightning, send down a Rain which is very different from that pure Snow which falls in a sharp Frost; and is far more acrid, and more disposed to froth. And hence Summer

All Oils also.

Rain, or Rain produced in hot weather, is always fruitful, whereas that in cold is scarcely endued with any such quality.

And Salts.

If you consider now the native Acid, austere, those that come the nearest to alkaline, and the saponaceous Salts of Plants, procured by crystallisation, fermentation, putrefaction, and combustion, you will find that all these do, sooner or later, disappear, not one of them excepted; since all these Bodies when they are freed from their fixing Earth, ascend up into the Air.

Nay even Earth.

Nay, and that very Earth too, which furnishes a fixed Element to Plants, does by its fineness acquire such a disposition, that it flies off, and is carried aloft. For pray, does not Soot, collected at the very top of a Chimney, from the volatile Smoke of a burnt Vegetable, yield, by a chemical distillation, a remarkable quantity of pure Earth? Hence, therefore, we are certainly assured, that Smoke which floats at liberty through the Air, carries along with it real Earth, mounts with it aloft, and widely disperses it through the Air. Not to mention the Winds, which sweep away the *Ægyptian* and *Lybian* Sands in Waves, as it were, through the Air, and carry the Ashes of Mount *Ætna* to prodigious distances. What think you of the Sparks of *Vesuvius*, scattered above a hundred miles through the Air? *Phil. Transf. Abr.* Tom. II. 142. What of the Ivy-berries dispersed over a vast deal of Ground? *Ibid.* 144. The little Fishes? *Ibid.* Or the masculine, seminal Dust of Vegetables? *Phil. Transact.* 168. p. 911. Hence, then, from these observations it is clear, that all the Elements of Vegetables may be carried into, and intermixed with the Air.

And also intricate parts of Vegetables.

But it is likewise certain, that parts of Plants, and those pretty considerable ones too, are carried into the Air, and are born up along with it to an incredible height. Consider the Seeds of downy-seeded Plants, which are carried up to the tops of the highest Towers, and there, as one sees daily, if they meet with ever so little Earth, propagate their *Species*. The celebrated *Tournefort* too has elegantly shewn from observations, that the Fungus's, which are almost all seminiferous, by means of the Air, disperse their invisible Seeds all about, which meeting with a proper Soil, thrive and spring abundantly. Mosses, likewise, and the mucilaginous and capillary Plants, as also the *Epiphyllouspermophææ*, or those which bear their Seeds upon their Leaves, scatter and diffuse their Seeds to very distant places. Nay, and even the small seminal dust of the Male-Willow, being shaken from the *apices* of the Flowers, and carried by the Wind into places remote from those Trees, and afterwards, when the Wind was down, falling out of the Air, has been falsely taken, by persons unacquainted with these things, for Flower of Brimstone, and afterwards believed by the credulous Vulgar to be a Shower of Brimstone. *Vide Phil. Transact. Abr.* Tom. III. And if such a small Dust should happen to be of a remarkable red colour, why should not the Vulgar for the same reason have asserted, that it had rained Blood? Were there not Ashes thrown out of a vulcano, and carried by the Wind, in the year 1633, the space of one hundred miles! *Phil. Transf.* No. 21. p. 377. But these are things not to be wondered at, since that excellent Philosopher *Mariotte*, in his treatise of *the Motion of Waters*, p. 334. observed in a Cloud that poured forth a shower of Hail, that the Air had carried this Cloud for fifty *French* miles. If we reflect, therefore, upon these things, we must naturally believe, that there are a vast number of surprizing things in the Air, and produced

by it; all which are intirely owing to a mixture of vegetable Substances that are distributed through it.

And if you enquire, in the next place, whether the parts of Animals are contained likewise in this Air? We answer, there is certainly a great quantity of exhaling Spirits, and those wholly peculiar to every Animal, and distinguished among Physicians by the name of the perspirable Matter of *Sanctorius*, that are continually dissipated through the Air from living Animals, and adhere to other Bodies; and by these Spirits it is that your Dogs, that follow by scent, distinguish so accurately the Animals from which they exhale, and follow those particular ones over large tracts of ground. And how full the Air is frequently of contagious Particles, exhaling from Animals, appears evident from the Infection too often observed in Diseases.

The Spirits
of Animals
are contained
in the Air.

But again, the excrements continually discharged by every kind of Animal, are in so short a time dissipated and disappear, that we are hence certainly convinced, that the whole quantity of excrementitious matter will be always dispersed into the Air, hardly leaving so much as the lightest Dust behind it. In the hotter countries, the Dung of Animals, being exposed to the open Air, becomes perfectly volatile by the Heat of one single Day. And even in our own country, which is not so hot, the very Dunghills are quickly consumed. And as for Urine, how quickly does that spontaneously become perfectly volatile, and exhale?

And their
Excrements.

But there is something in this affair still more remarkable. For pray tell me, does not an intire Whale, the largest of Animals, when in hot summer weather it is by the Sea thrown dead upon the Shore, I say, does not this Animal quickly infect the places, to a great distance about it, with a pestiferous stench? And is not the whole of it resolved into volatile infectious particles, so that at length there remain only some whitish Bones, the whole mass of the other parts being converted into volatile matter, intirely scattered up and down in the Air. What vast numbers of Carcasses of Elephants, Camels, Horses, and of almost all other Animals, as well as human Bodies, that are the Carnage of War, remain from time to time unburied, and are resolved into putrefaction, become volatile, and dissipate almost all their Elements into the Air? Hence, therefore, it follows, that Bodies of Animals are, from their own natural disposition, as much entombed in the Air, as in the Earth. And those very Bodies, likewise, which are buried in the Earth, are not then preyed upon by the Worms, but are quickly converted into a very light, volatile matter, which afterwards easily exhales into the Air out of the Earth itself. All the corporeal matter, therefore, that has ever entered into the composition of the Bodies of living creatures, has been carried up into the Air, with this difference only, that if the Bodies were burnt, this was brought about immediately; if left to rot in the Fields, more slowly; and still in a longer time, if they were interred; but yet even in that case, they have in time exhaled away. What wonder, therefore, if from the Air, there should be returned a Matter, of the same nature or kind with the food of the former Animals, which is capable of affording a proper nourishment to the Bodies, that are by this means to spring up afterwards?

Nay almost
all animal
Bodies.

But there is yet another thing upon this head, which it will be worth our while to take into consideration, as the right understanding of it will keep us clear of many mistakes. I assert then, that the very Eggs, impregnated with the

And their
pregnant
Eggs.

the fruitful offspring of their respective Animals, are carried up and down the Air. For the excellent *Redi* has demonstrated, that all Insects, without exception, are generated, by the copulation of Male and Female: *Leeuwenhoeck* has proved, that the Seed of the Male lodges the first Embryo in the Egg of the Female: And *Boyle* has made it appear, that pregnant Eggs will not exclude their young, except they are in the open and the fresh Air. Being furnished, then, with these Observations, I purposely took a piece of Flesh, which had been kept a pretty while in boiling Alcohol, and was afterwards rubb'd over with some bright Oil of Turpentine, and fastening it to a long small thread, hung it up in moist warm Air, in a place where it was imagined there were no *animalcula*, and the consequence was, that in a little time after the suspended Flesh was full of living Maggots, which were devouring whatever of the succulent parts remained in the Flesh. In this case, then, the Eggs, from which these *animalcula* were produced, could not possibly come at the Flesh, but by being born along through the Air, in which it was suspended. How much do the Farmers experience the truth of this to their detriment, when in a warm spring, certain Winds very suddenly infect the Trees with numberless Vermin, which in an instant, as it were, are produced from their invisible Eggs! But give me leave to mention one thing farther, that is still more remarkable, and that is, the Rains that frequently happen among the *Negroes*, which strike a man with such a sudden chillness, that it makes him shudder. These Rains fall in drops, of an inch diameter, which, if they come upon the Skin, eat into it; but if they lodge on any Garments, produce living Worms, and Moths, *Aët. Lips. Suppl.* Tom. I. p. 425. Many other things of this kind might be here taken notice of; but these may suffice, to let the Chemists understand, that the new and wonderful *Animalcula*, which are oftentimes produced in Bodies, and even, perhaps, while they are at work upon them, owe their Being intirely to little Eggs, which are thus carried about in the liquid Air, and not to the efficacy of any chemical Substances or Operations. Let them, therefore, be always mindful of the nature of the Air, and its very wonderful fecundity, before they deduce the origin of such appearances from any other causes. But the knowledge of these things at the same time, likewise, is not less necessary and advantageous to the Physician, and Natural Philosopher.

Fossils in the
Air.

But we must not detain you too long upon this head, and therefore let us now pass on to Fossils: For Fossils, I am certain, are likewise discovered in the Air. Fossils, say you, in the Air! 'Twere as reasonable to suppose Castles there. But please to hear only what I have to offer upon this head, and then you yourselves be judges.

Fossil Salts.

Do not, then, all fossil Salts whatever, though ever so fixed, if they are dissolved in Water, (especially in that which they attract from the Air) and are afterwards digested for a long time in a putrifying Heat, and are then distilled with a great degree of Fire, and have their fixed *Residuum* calcined with a strong open one, and then dissolved in the Air: Do not, I say, all fossil Salts whatever, managed after this manner, at length fly off into the Air? This is a Truth which a great Chemist communicated to the World more than an hundred years ago. Not to mention the distillation of these Salts, with Sand, Bole, Brickdust, Potters and Tobacco-pipe Clay, performed with the intensest Heat! Do not the Chemists every year convert, by this method, many thousand

land pounds weight of such Salts, into acid volatile Fumes, which they call Spirits? And does not every such chemical Operation infect the very Air? And does not this Air destroy the Bodies that are exposed to it? The single and simple mixture of Oil of Vitriol, Oil of Alum, or of Oil of Sulphur by the Bell, with Nitre, Sea-Salt, or *Sal-Gem*, converts in an instant those very fixed Salts into Fumes, so volatile that they can hardly be confined, with which the Air is in a short time so strongly impregnated as to carry those Salts to great distances all around. But infinite are the Methods by which the same thing is effected. Before the industrious *Glauber's* time, indeed, this admirable method of thus changing Salts, was not discovered. But who will pretend to determine how many Methods lie hid in Nature even at this day, by which the like conversion from a fix'd to a volatile matter may be brought about? The Vapours about Mines, which are often so fatal, that no living Creature can breathe in them with safety, sufficiently prove, that Nature herself thus disperses Salts through the Air, and consequently, has secret Methods which we are not acquainted with, for performing the very same Operations. In the mean time, however, it is true, that this happens only in certain parts of the Earth; namely, in those places where there is plenty of such a matter, and where likewise the means are not wanting, for working upon it after this manner. And it is likewise as certain a truth, that even those saline Vapours are elevated only to a certain height in the Air, and that not a very considerable one. And upon this foundation it was, that the Adepts asserted long ago, that the Air was divided into certain distinct *Strata* or Beds, each of which contained a distinct kind of Exhalations and Vapours. Hence, then, it is evident, that by the means of Water, Heat, Digestion, Solution, Exsiccation, Distillation, Calcination, Combustion, Mixture, Adunation, and Separation, Fossil fix'd Salts are rendered volatile, and are thus intermix'd with the Air.

And as for the principles of Fossils, which go by the name of Sulphurs, Next Sulphurs. these, whenever the Fossils are burnt, are intirely carried up into the Air, and being intermixed with it, disappear, the saline acid part changing into a suffocating Fume, and the oleaginous part being attenuated by the action of the Flame, and flying off in an invisible, or a sooty black Vapour. It is very certain, that hardly any thing at all of these parts remains in the Earth. Sulphur now itself, when alone, is carried into the Air in form of an impalpable Flower, and is there dispersed about. But when it is mixed with other Bodies, it often acquires a surprizing volatility. The Chemists have taken notice of a great many methods, both natural and artificial, by which Sulphurs are so changed, that they fly off into the Atmosphere, and carry up other things along with them. In Mines, from time to time, there appear pinguious, stinking, suffocating Fumes, pretty often very troublesome to the Miners, to which, if the Flame of a lighted Candle is applied, they instantly take fire, not without extreme danger to the Workmen. But it is certain, that Arsenicks, Orpiments, Cobalts, Sulphur of Antimony, Bismuth, Zincq, and other Bodies, furnish the matter of these Vapours. We are likewise informed of the falling of a shower of Brimstone, attended with Lightnings, which when it was once on fire, could neither be extinguished by Water nor Motion. *Nov. Literar. An. 1684. p. 63.*

In the last place, Metals themselves have been found to be so far changed, Lastly, Metals themselves. that they likewise, under the form of a volatile Fume, have been scattered up and

and down in the Air. This is universally known to be true of Mercury, which when agitated only by a Fire of 600 degrees, flies off, and becomes invisible. And if the Air impregnated with it, surrounds, and is applied to a human Body, how wonderfully does it penetrate it, and how quickly does it throw it into a Salivation! But besides, while it thus flies off, it carries up and bears away with it some part of certain Metals; as appears from the distillation of Lead and Tin with Mercury. Nay Lead, Tin, Iron, and Copper, if they are disposed in a very strong Heat, at length disappear, by means of the volatility they acquire there, and thus far are dissipated likewise into the Air. A great part of imperfect Metals is carried off too by Lead in the test. But when Cobalts, Arsenics, and the like rapacious Sulphurs, are intimately united with Gold and Silver Ore, the Particles of the Ore being by this means rendered volatile, when they come to the Fire, they carry away these noble Metals to that degree, that to the great damage of the Owner, a good part of them both is lost; which by a gentle calcination, and the addition of some fixing Powders, might be intirely preserved. Hence, therefore, it appears, what an abundance of Gold and Silver may be raised up into the Air. Nothing, indeed, seems a greater Paradox than volatile Gold, and yet we are certain from undeniable chemical Experiments, that if you take common sublimate of Mercury, and rub it well with Gold reduced to Powder, and then distill it in a Retort with *Regulus* of Antimony, the very Body of the Gold will ascend in form of a red Oil, and become perfectly volatile. By Sulphur, likewise, calcined Vitriol, and *Sal-Ammoniac*, mix'd and apply'd according to Art, almost all Metals may be rendered volatile in the Fire. No wonder then that in clear Weather, there very often appear about Mines sudden Fumes, which extinguish the Light of a Torch. See *Boyle's Works*, Vol. I. p. 52. since even the most dense Bodies may, in the form of a Fume, be so carried up into the Air, as that it can hardly be determined what Bodies they were. But there is another cause which is frequently concerned in this affair, and which likewise impregnates the Air with these metallic parts, and that is the Air itself abounding with Salts and Sulphurs. For as I have already shewn above, that the whole Air is full of Salts and Sulphurs; and as it appears from what I have now delivered, that those Salts and Sulphurs can carry aloft even Metals themselves when they are dissolved, it is easy to apprehend, that the Air itself can by this means effect that the parts of Metals may be suspended and float about in it. Are not Iron, Copper and Lead, by the contact, and motion of the Air always, and that in a short time too, turned into a *Calx*, Flowers, and a *Scabs*? And are they not hence converted into Rust, a bluish Mould, and a *Cerufs*? And have you never observed, that when after these changes, they are reduced to an impalpable Powder, they fly away, and are carried through the Air by the Wind. I confess, indeed, that Silver, Gold, and Tin, are less incident to these alterations, because the volatile Acids of Nitre, and Sea-Salt, which are the proper dissolvents of these Metals, are hardly ever dispersed through the Air, except about the Laboratories of the Chemists. The Air in *America*, indeed, is of so corroding a nature, that it consumes the Tiles of the Houses, stony Bodies, and almost all Metals; as the *English* unanimously agree of the Air of *Bormudas*; for even Metals themselves perish there very soon. And that surprizing *Phænomenon*, which in all ages has been observed by Miners, seems likewise to be owing to the

the residence of these metallic parts in the Air, viz. that the fossil Glebes, when they are dug out of the Earth, and are exposed to the Air, are affected by it in a very extraordinary manner. How frequently is it seen, that Marchasites, the Pyrites, vitriolic Stones, and metallic Substances that are quite exhausted, are so acted upon by the Air, that they increase, come to maturation, are changed, renewed, and afresh impregnated, and become again enriched with a true metallic Offspring. In reality, the Air seems to be the grand universal distributor of the Seeds of Bodies, which being plentifully stock'd with every kind of Matter, commits to the Earth the Elements of Bodies it had before received from it, and thus generates most kinds of Bodies, rather by means of a revolution, than a new production. 'Tis certain, that Dew being changed by Distillation, has yielded a Liquor, which stained Glass with the Colours of the Rainbow, penetrating so deeply into it, that it could neither be removed by *Aqua fortis*, Oil of Tartar, or a strong and long continued friction; and yet at the same time the Liquor itself was so subtil, that it burnt in the Fire like Alcohol; *Republic of Letters*, T. I. p. 590. Certainly this effect is very like that of a metallic Tincture upon Glass. *Philosophical Transactions Abridg.* T. II. p. 143.

Thus, then, Gentlemen, the few things I have laid before you, are sufficient to instruct us in our chemical Inquiries, what notion we ought to form of the Air. In reality, it is to be considered as a true Chaos of all things intermixed and compounded together: For in it there float up and down the attenuated Particles of all Bodies whatsoever. And since these little Corpuscles are always in motion, they may, by running among one another in this aerial space, produce all those wonderful operations of Nature, which are owing to the efficacy of particular Bodies: But these are almost infinite. So that indeed, it is not at all to be wondered at, that there are produced and appear in this scene of the Air, such extraordinary, and frequently such terrible events in Nature, as never happen any where else: I mean the Meteors. In this Air there doubtless must be Bodies that are endued with a magnetic vertue, which by their mutual attraction, repulsion, cohesion, rarefaction, and by infinite other methods, must every where excite stupendous *Phænomena*. An instance of this you have here before you. In my right hand I hold a small open glass Bottle, in which there is an alkaline Spirit of *Sal-Ammoniac*; and in my left I have another, in which there is Spirit of Nitre. You see, that whilst I keep these Bottles at a distance from each other, nothing at all appears extraordinary; but that as soon as ever I bring them gradually so near towards each other, that the Vapours issuing from the two Bottles, begin to meet with one another, there immediately, in the place where they thus mix, appears a little Cloud, arising from the concurrence of the Alkali and Acid in the Air. If an Amalgama prepared with Tin and Mercury is distilled in a Retort with Spirit of Sea-Salt, it yields a Liquor, which, if it is kept in a close Vessel, produces no effect; and yet if it is exposed to the open Air, tho' many years after its preparation, it immediately goes off in a very thick Smoke. But Nature is every where full of the like instances. We know not what other hidden Salts there may be besides in the Air, that we are not acquainted with, or with what vertues they may be endued. Nor are we less ignorant what Spirits and Oils may float up and down in it; tho' in the mean time, from the particular Nature of those un-

From what has been said is gathered a true knowledge of the Air,

known Salts, Spirits, and Oils, such stupendous effects may be produced, as are never observed to proceed from any other causes. If the distill'd Oil of Sassafras happens to meet with *Glauber's* Spirit of Nitre; what a terrible effect is produced in an instant? An effect hardly to be exhibited by any other Experiment. If at any time, now, there should chance to get into the Air a number of Particles endued with the like properties, and these should be there mixed together, very strange and surprizing appearances must necessarily follow. Certain times, it is evident, do present us with *Phænomena*, that are never seen at any other. To the production now of these rare and very extraordinary effects, it is possible that the Comets, Meteors, various Aspects of the Planets, and perhaps the Stars themselves, may principally exert their influence; whose actions may be very considerable, on account of their attraction and repulsion, of their Heat, Light, and Cold, and of the *Effluvia* which they generate and emit.

In consequence now of all the things I have here mentioned, this Air is of a quite different nature in particular places; first, on account of the Land or Soil, or the part of the Earth which the Air under consideration hangs over: For according to the various Bodies with which the Earth abounds in any particular part, the Exhalations and Vapours that arise from it will possess as various qualities, and for this reason, the Air in that part will be full of Corpuscles, that are not to be met with any where else. The truth of this has always been confirmed by numberless Examples. And hence it will come to pass, that in such particular parts of the Air, certain Experiments may be made, that will never succeed in any other. In the second place, a very great diversity is here observed likewise, in respect to the Soil, in different places, according as Men inhabit it, and keep Animals there, and according as they dung and turn up the Ground, and exercise various Occupations there, and by this means raise up almost all kinds of Bodies into the Air: On which account again, an infinite number of changes are observed to happen, which are not to be effected elsewhere. A certain Chemist, for instance, in his Laboratory, where he was daily employ'd in the distillation of large quantities of Vinegar, expos'd to the Air some pure, dry, alkaline Salt of Tartar in a glass plate. The Air, of consequence, being full of acid Vapours, dissolved the Salt into an Oil of Tartar *per deliquium*, and at the same time so closely united the acid parts of the volatile Vinegar with the Alkali of the Tartar, as at length to convert the saturated Mass into a *Tartarum Regeneratum*, or regenerated Tartar, which melted in the Fire like Wax, and yielded a very noble Remedy for the resolving of viscid tenacious humours, in almost all Diseases. He was mightily pleas'd therefore with this production, for he reckoned he had now discovered the great secret of the Alchemists for Incrating, according to the language of those Gentlemen, a fix'd alkaline Salt: But when afterward he attempted to repeat the Experiment in another place, where there was not so great and constant a quantity of Vinegar in the Air, he met with nothing like the former success. The same thing might be farther made appear by a vast number of instances, but you yourselves are sufficiently apprised of it. Consider then a little, how prodigiously the Air may be changed in any particular place, when a great Earthquake has occasioned exhalations to arise there very different from what there did before. And this is again confirmed by History, which

which informs us, that certain parts of the Earth have become uninhabitable, by reason of the abominable stinking Vapours with which they have been infested after Earthquakes. But again, inundations by Rain, overflowings of Rivers, and the breaking in of the Sea, make such alterations in the Atmosphere, by means of the humid Vapours, and Exhalations from putrified Bodies hence occasioned, that the whole nature of the Air, in those places, is intirely changed. The very Winds, likewise, as they carry the Air with all its contents from one place to another, must always bear along with them something from the places from whence they began to blow, and consequently are thus always varying the contents of the Air, continually carrying off from particular places the matter peculiar to them, and supplying them again with what they just brought from some others. From which cause likewise, there must needs happen in chemical Operations, a remarkable diversity. And as for the influences of the Heavens, particularly in respect of the various Aspects of the Sun and Moon, their accessions, recessions, perpendicular or oblique irradiations, conjunctions, and oppositions, what changes must these produce in the Air, by their attraction, repulsion, and the Heat and Cold that depend upon them? What variation must they cause in the Vapours and Exhalations that are carried up from the Earth into the Air? But there is one thing farther on this head, which, as Chemists, we ought to take particular notice of, and that is, the vicissitude of the seasons of the year, which is here of such efficacy, as is wholly incredible; even setting aside that which arises from the various actions of the Sun in this stated annual course. You'll understand what I mean, in the following manner. If the Sun on the tenth of *March*, in a certain altitude, and with a certain degree of Heat exerts its Power on the Earth, it then acts on a Body, which in the preceding Winter, being lock'd up by the Cold, has kept in and accumulated, under an icy or cold Crust, its own proper Exhalations, and at the same time, has received and retained whatever came down upon it out of the Air: Hence, as soon as it begins to thaw, and the Earth resolves itself into a loose Mould, the first succeeding Heat of the Sun acts upon this fertile pregnant Body, and immediately fills the whole Air with Vapours: On which account a vernal Heat hardly ever succeeds a Frost of long continuance, but there presently follow Showers, Thunders, and Lightnings, and an igneous Vigour appears in all Animals and Vegetables. But now, when on the tenth of *September*, the Sun at the same Altitude, and with the same degree of Heat, acts upon the Earth, it then finds it parched up, and exhausted by the Heat of the preceding Summer, and not yet moistened with autumnal Showers; for which reason, neither the same Heat in the Earth, or Air, will produce the same effect, nor will excite this vigour in Animals and Vegetables, as it does in the Spring. These few things then will be sufficient to let us easily see the variety there is in the Atmosphere, according to the diversity of the season of the year, as far as it arises principally from this cause; a Speculation very useful both in Chemistry and Natural-Philosophy. And, indeed, it's plain the Chemists had some insight into this matter long ago, when they attributed to the vernal Rain, a vertue so much superiour to that of the autumnal, produced in the very same degree of Heat: For they found that this *Lixivium* of the Air brought along with it out of the Air, very different Vapours and Exhalations, according to the diversity of the season now explained.

A quality in
Air intirely
singular.

Before we leave the examination of the various Bodies that are contained in the Air, and of the different Powers which prevail in it, we must yet take under consideration one quality of it, which is very salutary and necessary to the life of Animals and Vegetables; a quality which has not been yet accounted for from any other property of the Air, but by a diligent inquiry, however, may possibly, hereafter, be come at the knowledge of. Whether, now, this latent vertue of the Air is actually drawn out of it by Animals and Vegetables, and hence is in a short time exhausted and consumed; and whether, when it does thus fail, the Animal dies, no-body is, I think, at present able to determine. This, however, is certain, that if a small Bird is put into a large Receiver, full of common cold Air, and the Receiver is then very closely stopt, the Bird will grow sick and vomit within a quarter of an hour, and die in the space of half an hour after. *Boyle, Of the Air.* 184. A Fish kept in Water in a Vessel well closed, without renewing the Air, dies in a short time. Fish likewise die in Ponds that are every where frozen over, and quickly perish in Water out of which the Air is exhausted. *Hist. de l' Acad. Roy. des Scien.* 1699. 240. 1701. 46. and *Mem.* 224. Flame, and a red hot Coal, quickly go out in Air that is close pent in. The little Eggs of any Insects whatever, being accurately stopt up in glass Vessels, do not produce their young, tho' assisted by a kindly Warmth. The Seeds of Plants likewise, duly moistened, and sowed in the best Earth in close Glasses, do not grow, or give any signs of active Life, tho' excited by a due degree of Heat. On the other hand, the upper Surface of Blood that is exposed to the Air, is of a bright scarlet colour, whilst in every other part, where the Air don't come at it, it grows as black as the juices of the Cuttle-fish: And yet, as soon as ever this black part is laid open to the Air, the black colour is immediately changed again into a scarlet. All these Experiments then make it appear, that there is in the Air a certain hidden vertue, which cannot be accounted for from all the properties of the Air, which have been hitherto discovered. *Sendivogius* maintained it openly, that there lies hid in the Air the occult Food of Life; and other Chemists have asserted the same: But what that is, or how it acts, or what is the proper effect of it, is a matter still in the dark. Happy the Person that shall happen to discover it. Let this Hint suffice for Persons that are hitherto ignorant of it, is it not the elastic part of the Air alone?

Hitherto explained by
no-body.

For my own part, I confess, I cannot apprehend, that either the Natural-Philosophers, or Physicians, have yet discovered the physical cause of this wonderful quality of Air. I have seen, indeed, a great many conjectures upon it; but they have almost all fallen of themselves. After all that has been said then, we have now a proper opportunity in the last place, of treating a little briefly of the proper weight of the Air: And to this purpose, if you please, let us take the sum of what has been laid down.

The weight
of the elastic
part of
the Air.

The Air then is full of Water, which is ponderous, solid, and not to be condensed by any weights. With this Water, the Air is so plentifully stocked, that Salt of Tartar, upon Experiment, has attracted so much Water out of a small quantity of Air, contained in a glass Vessel close stopt, as to grow sensibly moist. Besides Water, too, almost all kinds of Bodies are contained in the Air, and dispersed up and down in it: All which Bodies taken together, must at least be as heavy as the Water. But these Corpuscles, likewise, as they are there in a liquid form, can scarcely be driven closer together, by the force of any imposed

imposed weights. If therefore from a given portion of Air, all that truly ponderous Matter, which, as has been demonstrated, the Air naturally receives from all kinds of Bodies, was very accurately separated from it, how much weight do you think would there remain belonging to its real elastic part? Undoubtedly you perceive, unless I am exceedingly mistaken, that there would remain but a very little: Nay, if from the assistance of so many Experiments, we may be indulged a conjecture, perhaps there would be really none at all. For let but the eight hundred and fiftieth part of the whole space of a cubic foot of Air be filled with Vapours and Exhalations, not elastic, and with dusty Particles floating up and down in it, then the remaining elastic part of the Air will have no weight at all. And hence it might come to pass, that the Air in that compass could never be reduced into a less space than the $\frac{1}{850}$ of the whole, notwithstanding the *Newtonian* Law should constantly hold good in the elastic part; namely, that the Elements of Air always endeavour to recede from one another with so much more force, as the weight is greater by which they are compressed. And from this supposition it would likewise necessarily follow, that when the other parts are contracted into a space 850 times less than the former, then the elastic part cannot be reduced closer by any weight whatsoever, since all that space would be then filled up with Water, and other incompressible Bodies. And this exactly answers to the Experiments of the famous *Halley*, and the *Academy del Cimento*, who assert, that the Law of the reduction of Air into spaces, proportional to the compressing weights, does not hold good beyond that space which is 850 times less than that which is taken up by the common Air. *Hist. de l' Acad. Roy. des Scien.* 1703. 7. *Mem.* 102. We ought not, however, thence to conclude, that the purely elastic part of the Air, if it could be made trial upon alone without the mixture of other Corpuscles, could not, by the same Law, be condensed a great way farther. And who will pretend to determine how far? Perhaps this would always be the case.

Perhaps it
has no
weight at
all.

For these reasons, I have frequently considered with myself, whether the supreme Being has not created both Fire, and purely elastic Air, intirely without gravity, nor tending naturally to any particular point, but equally distributed throughout the whole Universe, and that under this Law, that the Fire should always so act upon the Air, as never to suffer it to be at rest, no not even in the extremest Cold. For, if in the upper region of the Atmosphere, the Heat of the Fire is less, the Air likewise in the same proportion being there less condensed, as there are fewer heavy Bodies to compress it, must be always rarer, and consequently will be so much the easier kept in an ebullition by a less degree of Fire, and will at all times be agitated with a tremulous motion. What room is there here then for admiration! What a mighty moving power upon every thing, left at any time they should be at rest! But it's very likely you will be apt to think with yourselves, if the Air, with respect to its elasticity, be without weight, what is the reason then, that it is not rarer about the Earth? Why, let us, Gentlemen, only consider, that its Elements are not so easily to be disengaged from the other Particles with which they are intermixed and intangled, and consequently, that by this means it will be compressed by the other Bodies that are incumbent upon it; and then the reason of this *Phænomenon* will be very evident.

A duumvi-
rate of mo-
tion in Fire
and the elas-
tic part of
the Air.

And:

The properties of the elastic part of the Air.

And thus I might here have put an end to our History of the Air; but there remains, however, a small, but very valuable Article, which may still be added, *viz.* the demonstrating this purely elastic Air by Experiments, and the prosecuting it in its wonderful effects. And upon this head, whilst I have consulted a great number of Authors, I have found the excellent *Mariotte* to be the principal one, who has broke the Ice, and led the way. Pursuing then the steps of this famous Gentleman, I have digested these Experiments in the following order.

EXPERIMENT I.

Elastic Air adheres to Solids.

I have here in my Hand a Plate of pure Silver, curiously polished, and very carefully cleaned, and as warm as the present temper of the Atmosphere, *viz.* 52 degrees. This Plate, as you see, I immerse gently, without any concussion, into very clean Water, of the same degree of Heat, in this glass Vessel; and yet you see there are formed aerial Bubbles, sticking to the Surface of the Silver, thence rising up through the Water, and then bursting asunder. This, therefore, upon examination, being constantly the event, we may hence conclude, that common Air, by its invisible Particles, adheres in such a manner to the solid Surface of the Metal, that it descends with it through the Water, keeps its hold by a certain viscid tenacity, and will not give way, and leave its Surface, till it is forced upwards by the weight of the Water. When this Silver Plate, therefore, is moved through the Air, undoubtedly the Air next its Surface will adhere fast to it, till by Wind, Heat, or a rapid motion, it is dislodg'd from it, and then at last it yields up its place to some other Air that succeeds it. This property now of merely elastic Air, ought well to be taken notice of in chemical Operations. For since it sticks only to the Surface of Bodies, not being able to enter into their solid Mass, 'tis evident that Bodies, when they are minutely divided in the Air, and consequently have their Surfaces greatly multiplied, always carry far more Air with them into the Receiver, than they would have done in a single solid Mass. And for this reason, the Air that is generated in the solution of Silver Dust by Spirit of Nitre, is not to be supposed to proceed from the Spirit of Nitre, or the solid Mass of the Metal alone, but partly likewise from the very Air which is convey'd on the Surfaces of the Particles of Silver. If the Experiment is made with a Plate of Gold, the *Phænomena* are the same. If very solid polish'd Gold then attracts Air after this manner, all other Bodies certainly will do it much more. All Bodies, therefore, when they are immersed in Water, carry Air along with them; tho' those Bodies do it more so, which are rough, and whose Surfaces consequently are greatly increased. If at the same time too they are fungous, spongy, and full of Pores, they will carry with them still a much larger quantity of Air through the Water; especially, if such Bodies are dissolved into their smallest parts by the dilution of Water. This then is the first method of demonstrating the adhesion of elastic Air to solid Bodies.

EXPERIMENT II.

And Fluids.

Again; you see this pretty large Cylinder, which is bright, clean, transparent, and dry. Please to observe, into this Cylinder I pour pure Water, till the Vessel is almost full. This Cylinder, now, thus full of Water, I so apply to the Air-pump, that by means of it, I exhaust the Air that rests upon the Surface

Surface of the Water ; and at first you perceive no alteration in it. As the Atmosphere, however, now, is a great deal diminished, you perceive Bubbles of Air appear ; and in what numbers ! How swiftly are they carried upwards ! How quickly do they increase in magnitude ! But whence now do they arise ? Why certainly, as far as we can any way discover, from the Surface of the bottom and sides of the Vessel, or of the Water. And hence an unwary person, who should see this Experiment only, might be induced to imagine, that all the Air, which by this method is fetch'd out of the Water, lay concealed only between the concave Surface of the Glass, and the convex Surface of the Water. But this opinion will by other curious Experiments be refuted hereafter. In the mean time, however, this we are assured of, that Air adheres to the Surface of Glass, and Water, with the same tenacity that appeared in the preceeding Experiment.

EXPERIMENT III.

But the very Air itself, by its Surface, adheres to the Surface of other Air, with a pretty remarkable tenacity, notwithstanding its Elements seem to fly from one another. The demonstration of this, which indeed has been given in a former part of this work, I repeat again in the following manner: This Glass Vial, which from a large spherical Belly, runs out into a long cylindrical neck, the diameter of which is nearly 4 geometrical lines, I have filled with Water ; and now I invert it in such a manner, that the mouth of the neck, which is open, points directly downwards, and yet not one drop of Water falls out ; nor does there enter one bubble of Air ; a manifest indication, that the fine Elements of Air do not here easily recede from one another, but, by a certain adhesion, cohere together. (This Experiment I exhibited formerly, when I was treating of the divisibility of Air ; but as I am now considering Air as elastic, or very light, I am obliged to repeat it again). For if the very light elastic Particles of Air were as easily separable from one another, as the united parts of Alcohol are, then the elastic Particles of Air passing through the Water, would make their way upwards ; and the Water would proportionably run out of the Glass, as we saw on the foregoing occasion, when we set this same Glass in Alcohol that was coloured. See p. 258. and the following. And that the effect we are speaking of is chiefly to be attributed to such a tenacity of the aerial Particles, is confirmed by the following Experiment. The same Vial, filled with a very strong *Lixivium* of Salt of Tartar, I immerse again, thus, into distilled Oil of Turpentine. Do not, now, the viscid parts of the Oil ascend, through this more ponderous *lixivium*, far more slowly than Water or Spirits of Wine ? Most certainly. You will say, perhaps, that the repulsion there is between the aqueous Particles, and the oily ones, is the cause of this *Phænomenon* ; and that the Air is repell'd in the same manner by Water. I grant it. But in the mean time, you see, that this slowness in the Air in ascending appears equally evident, whether the Vial is filled with Water, Alcohol, Brine, any *Lixivium* whatever, or even with Mercury. Hence, therefore, It seems not altogether improbable, that the tenacity of the elastic parts of the Air, among one another, is greater, in these instances, than in the other Liquids. When the elastic parts of the Air, therefore, are once united together, they seem to be less easily separable, and less easily divisible into their minute parts ; and, consequently, they appear to be mixed with other Liquids, with more difficulty than any other Fluid we are at present

present acquainted with. I know very well, that all the Philosophers I have hitherto consulted, are of another opinion, and think nothing more true, than that the Air immediately enters any Liquid whatever that it can but come at. But careful observation obliges me to think in a quite different manner. For if I fill two thirds of the capacity of this Vial with any Liquor whatever, and the other third contains nothing but Air, and I perfectly close it with a glass Stopple, and then shake the Vial over so long, I shall never bring the Water to be wholly mingled with the Air, but only large bubbles will be produced from the Water, within which the aerial Particles are entangled and rolled up, whilst the agitated parts of the Water form little spherical Bodies that keep them in; and thus, from a number of such Bubbles there arises a white Froth, consisting purely of Air and Water, into which they are again resolved; the diameters of these Bubbles being nearly three lines. But that you may see the truth of this Paradox still more evidently, be pleased likewise to take notice of the following Experiment. This glass Vial, the Mouth of whose Neck is open, and not four lines wide, is full of our common Air. This Vial, now, I sink thus perpendicularly under Water, so that the mouth of it, which is open, and points upwards, is quite below the Surface. The Water, therefore, now rests upon the Surface of the Air, and nevertheless does not descend into the Vial, but the Surface of the Air bears it up. Water, therefore, which is eight hundred times heavier than this compounded Air, cannot so divide the Particles of the Air asunder, as to insinuate itself among them, and descend through the Air. But there is another thing remarkable upon this head, which is as follows. This glass Vial is full of Water, and the mouth of its neck is 5 lines wide. This, as you observe, I so invert, as that the mouth points downwards; and now you see, that there arise not small, but large capacious Bubbles of Air; that they enter into the neck, through the Water, and make their way upwards, thus whole and united; and that they are not, while they pass through the Water, divided into very small parts, but ascend in form of large intire Bubbles. You perceive at the same time too, that the Surface of these Bubbles is at both ends convex, and that the Water accommodates itself to them in a Surface that is concave. But this appears still more distinctly, when I place the neck of this Vial in a horizontal position, for then these aerial Bubbles remain equally large, and being on all sides confined within the Water, shew very clearly their bulk, which they retain a long time together with their Figure, which is convex at both ends, as you see in the Plate. The same thing holds true likewise with regard to this convexity of the Air, in narrow glass Tubes full of Air, and open at both ends. For if you set them perpendicularly in Water, the Water will rise in the Air in such a manner, as to form a concave Surface on its upper ascending part; whilst the surface of the Air that is contiguous with this of the Water will be convex. This too you see in the Plate. All these things, then, considered together, seem to evince, that the Elements of the elastic part of the Air possess a determined and pretty considerable tenacity, with respect to one another. Those things, I say, taken all together, for I am not ignorant, that very celebrated Authors explain some of them from the attraction which is observed between Glass and Water.

Tab. VII.
Fig. 3.

Pl. VII.
Fig. 4.

Fig. 5.

EXPE-

EXPERIMENT IV.

I have here, three conical Glafs Veffels A B C growing narrow towards the top, and open ; and with plain or level bottoms. In one of them there is Water, as cold as the Air is at present, viz. 44 degrees. In another there is Water of the fame warmth with this place which we are in, which is about 91 degrees. In the third there is Water heated to the 150th degree. And I have chofen the Veffels pretty tall, that the Experiments I fhall exhibit may be the more conspicuous. Thefe Veffels then, thus prepared, I forthwith fet upon the Air-pump, under the Bell ; and immediately exhaust the Air. Do you not now very plainly perceive, that as foon as I have drawn out a little of the Air, a very large quantity of Bubbles are generated in the hotteft Veffel C, which are formed at the bottom and fides of the Veffel, and afcend, grow larger, and break afunder at the Surface of the Water, juft in the fame manner as if the Water was now really boiling, which notwithstanding is, perhaps, 70 degrees below the Heat of boiling Water in the open Air. In the Veffel B, however, where there was but juft now a heat of 91 degrees, you fee, there is yet no fuch agitation. But having now drawn out more Air by the Pump, there appears in B too, the like production of Bubbles ; fo that there is now an ebullition both in A and B, but none yet in C. Having now, however, drawn out a great deal more Air, an ebullition at length is produced in C likewise ; and all of it being now exhausted, the boiling continues for a very confiderable time. Hence then we infer, that pure elastic Air, in a certain quantity, lies infenfibly concealed in Water, without any difcovery of itfelf in the cold, and under the preffure of the Atmosphere ; and yet in the Experiments of the *Academy del Cimento*, Water, though it contains in it this latent Air, which is fo compreffible, could not in any manner be itfelf condensed by weights. For this reafon therefore we conceive, that the Air which infinuates itfelf into Water, is there lodged in the interftices which are left between the Elements of the Water, which are in contaft with one another, and cannot themfelves enter into thofe vacuities ; but that it does not interpoze itfelf between the Elements of the Water, where thofe Elements can naturally touch one another, and by this means hinder them from coming together ; for in fuch cafe, the Water, which contains this Air, would likewise be compreffible. Thus, then, we are certain, that the Air poffeffes only thofe vacuities, which are constantly left between the immutable Elements of the Water, and which are not to be altered or difturbed by any varied fituation of thefe Elements, being, perhaps, whilft it is at reft there, divided into its perfectly diftinct elementary Particles. Hence farther, we are induced to believe, that this Air, fo lodged in the Water, and not difcovering itfelf for fo long time in the Cold, requires, in order to its being retained there, that the Water be compreffed by the force of a ponderous Atmosphere ; but that when the particles of the Water are compreffed together by an effort lefs ftrong, then thefe latent Elements of Air elevate the incumbent Water, difengage themfelves from the interftices where before they lay quietly hid, and then leave thofe interftices empty of Air. In the third place, we fee likewise, that Heat difpofes the intercepted Air to extricate itfelf with greater eafe from the furrrounding Water ; and that in fuch manner, that the hotter the Water is, the more readily, in proportion, will the Air get out of it. Hence therefore,

Q q

when

There is
elastic Air in
Water, as ap-
pears by this
Experiment.

Pl. VIII.
Fig. A

when Water has boiled on the Fire for a considerable time, having by that means acquired its greatest Heat, it will have expelled almost all the Air that was contained in it. And in the fourth place, we learn likewise from Experiments, that every sort of Wine, Malt Liquor, and Spirits of Wine, do in Mr. Boyle's Air-pump discharge themselves of these aerial Bubbles so much the sooner as these Liquors abound with a greater quantity of inflammable Spirits.

And another.

Fig. 2.

But this other Experiment, which now follows, will make all these things more evident. You see I take a cylindrical Vessel AB, with a flat bottom, and fill it half full of common clean Water. I have likewise a spherical glass Bottle CD composed of a Belly C and a Neck D which I fill quite full with the same Water. Then with my Finger laid upon the Mouth D, and touching the very Water at the top of the Neck, I so immerse this Neck D into the Water in the Vessel AB that no Air can possibly enter into it, and hence the Bottle remains still quite full of Water, without the least Air at top. Both these Vessels then thus disposed, I put, as you see, under the Bell upon the Air-pump. And you observe, now, whilst I exhaust almost all the Air, that the Water in the Belly of the Bottle C descends by its gravity through the Neck D, into the Vessel AB, because the Surface of the Water in the Vessel AB is no longer pressed by the weight of the Atmosphere. In the upper part therefore of the Belly C above the descending Water, there is now formed a *Toricellium Vacuum*. Hence the Water is there pressed by nothing, but exists in *vacuo*. And by this means the Air which is in the Water in this Bottle, produces a vast number of Bubbles; all which make their way through the Water in the Neck and the Belly, towards that upper *vacuum*, and there bursting asunder, give you all the Air which is collected out of the Water in the Bottle CD. I leave every thing now in this state till no more Bubbles are formed, nor ascend into the upper part of the Bottle; and then, as you see, I let the Air into the Bell, which immediately pressing upon the Surface of the Water, in the Vessel AB, forces up the Water thro' the Mouth D into the Belly C; and now you perceive, that tho' there is a free communication with the external Atmosphere, yet the Water does not quite fill the whole Belly C, as it did before, but there remains in the upper part an aerial Bubble, consisting of true elastic Air, which was forced out of the Water in the former operation, in those little Bubbles, which were then produced, and there burst asunder. Nor were those Bubbles generated there, till the greatest part of the Air had been exhausted out of the Bell. Nor indeed do these little Bubbles ever arise from this Water, 'till it appears by the Mercury in the Barometer, that the weight of the Atmosphere under the Bell is diminished more than one tenth of the whole. Since, therefore, the greatest variation of the weight of the Atmosphere with us never exceeds one tenth part, hence there will never be any danger of Water's discharging the Air that is contained in it. But Water, likewise, made ninety degrees hot, and then freed in the Air-pump from a tenth part of the weight of the Atmosphere, does not even then send out its Air by Bubbles; and hence the Air likewise in the Fluids of our Bodies will never be separated from our Blood, or Humours, by the greatest lightness of the Atmosphere that ever is observed amongst us, as by a particular Experiment too I shall demonstrate hereafter. It happens, indeed, sooner in this hot Water, than it does in colder; but yet even here it is not observable, upon a diminution only of a tenth part of the aerial pressure. But you will

will be apt to ask me now, Gentlemen, and that very justly, how I know that the great Bubble in the upper part of the Belly is true elastic Air? This, I confess indeed, it is absolutely necessary that I should demonstrate. The reason then that I look upon this to be true elastic Air is, first, because, as you saw yourselves, it expands and contracts itself in proportion to the compressing weight; and in the second place, because if Heat is applied to it, it expands itself into a much larger Space, and if Cold acts upon it, it contracts itself into a far less: But that these are the peculiar and most certain marks of Air, who will go about to dispute? But there is another Thing still that must be cleared up, and that is, whether the Air produced in this manner be really exhausted out of the Water; or whether it only comes from the interstices between the Surfaces of the Water and the Glass; for this indeed seems to be evident to the Eye, as I observed to you but very lately.

But if I am not very much mistaken, there are not wanting arguments to prove, that it arises out of the very Water itself. This is very evident, if we consider, first, that a very different quantity of this Air is produced from the same quantity of different Liquors; for Mercury, Water, Wine, Spirit of Wine, Beer, Alcohol, Wine that is foul, and that is fermenting, Beer not duly work'd, and Must, differ incredibly in the quantity of Air which they thus generate *in vacuo*; whence it plainly appears, that this Air is separated, not from the Surface only, but from the inmost recesses of Water, and other Liquors. And if we add to this, that there are some Fluids, which in this way generate no Air at all, our opinion will be still farther confirmed. Thus, for instance, Oil of Tartar *per Deliquium*, tho' it is produced itself in the Air, will scarcely yield any Air, if it is treated in the same manner. And, which one would hardly believe, even the Spirit, which we call the alkaline, volatile Spirit of *Sal-ammoniac*, if it is very strong, will afford but an exceeding small quantity of Air, in the same Experiment. But there is another Argument, which will serve as a farther confirmation of this truth, of which I shall quickly give you ocular demonstration; and that is, that the whole quantity of that Air, which was produced after this manner, may intirely be absorbed again by the same Water out of which it was drawn, and that no more than that quantity, exactly, can by any art or power be forced into it. All which considerations, if you weigh them with due attention, will furnish you with arguments sufficient to convince you, that far the greatest part of that Air was really exhausted from the very Body, or inmost parts of the Water.

Within the Water itself.

And finally, we may add, that this Air, by the same Experiments, has been drawn likewise out of Vinegar, Spirits of Wine, Urine, Spirits of Urine, Oil, Water and Oil, express'd Oil, distill'd Oil, Milk, Blood, the Serum of Blood, Eggs, the White of Eggs, nay, and lastly, even from Mercury itself. But here let me observe, that if this Experiment is made with boiling Water, which has boiled continually for the space of an hour, hardly any Air at all will be got out of it; so that this doctrine stands upon a firm foundation.

And in all other Liquors.

EXPERIMENT V.

If Water is by boiling accurately deprived of all the perfectly elastic Air that is dispersed through it, and afterwards, being cooled to the temper of the Atmosphere, is exposed to the common external Air, then will the elastic Air spontaneously,

Air will enter into Water that is void of Air.

neously, and pretty quickly, enter into this Water, which is now void of Air, and again lodge itself in the spaces left between the interstices of its Elements, and that always to a determined quantity. This wonderful relative property between Water and elastic Air, is demonstrated to the eye in the following manner. Take the whole *Apparatus* of Vessels, made use of in the second part of the 4th Experiment, just now exhibited, where the elastic Air was collected at the top of the Belly of the inverted Bottle. If, then, that aerial Bubble is compressed with the machine used for condensing of Air, the Bubble will not by that means intermix with the Water: But if I expose this whole *Apparatus* to the external Air, then this Bubble will in a little time begin to diminish, and at last will so perfectly vanish, that there will not be the least Air left at the top, but the Belly of the Vessel will be again quite filled with Water only. And this Experiment is constantly observed to proceed in this manner, namely, that in the beginning, a great portion of this collected Air enters pretty quickly into that Water, deprived of Air, but that the little quantity that then remains makes its way in but very slowly. Hence, therefore, it follows, that Water will always imbibe again exactly the same quantity of Air as has been drawn out of it before.

But not into
Water satu-
rated with
Air.

* The event, now, of this Experiment is pretty extraordinary, when it is attempted with Water, which is already naturally saturated with Air. If therefore, instead of drawing the Air out of the Receiver, and thus forming a Bubble at the top of the Bottle, I take the same Bottle, and not filling it quite full, with my finger upon the Mouth, invert it into the other Vessel, then a Bubble will retire to the top of the Water in the Bottle, and if I then set by the Vessel in this manner, for the space of a year, the aerial Bubble I let in will never enter into the Water, but will always remain at the top, without being mixed with it. Nay farther, in what manner soever I shake these Vessels, I shall never be able to make that Air insinuate itself into this Water. This Bubble indeed would be divided into other small ones, but do what I could, it would never be mixed and distributed through the Water, in such a manner as to become invisible. I have tried what could be done by pressing, heating, cooling, shaking, and laying it up for some time; and yet still that Air constantly remained at top in the same quantity; nor was it possible to intermix any more with the Water, than what it had spontaneously taken in from the common Air.

* This Doctrine of our Author, that Air will not be absorb'd by Water that is already saturated, does not appear constantly to be agreeable to Experiment, as upon trial, at the hint of the learned Dr. *Jurin*, I observed in the following manner. I took a common *Florence* Flask, and filled it almost full of Water, and after letting it stand some time, with my Finger upon the Mouth of it I inverted it, and by this means procured a Bubble of Air at the top. I then, with my Finger still applied to it, immerg'd the Neck of the Flask into a wide-mouth'd Square, full of Water, upon which, drawing out my Finger, I left the Flask standing in the Mouth of the Square. In this manner I put it out of the way, and examining it from time to time, found the Bubble gradually lessen, till it at last intirely disappeared. This I repeated several times, with the same Success. When the Bubble was small, it was taken in in a few days, and as near as I could judge, faster in proportion than the large ones. The Diminution too of the large ones, at the beginning, was more sensible than afterwards, as I saw evidently in one of an inch and three quarters in diameter, set the 4th day of *June*, which, though it was considerably diminished the first month, yet is not this 10th of *December* reduced to an inch. Whether this, therefore, will be totally imbibed by the Water, or not, I cannot yet determine, not having made trial of so large a one before, but one of about $\frac{7}{8}$ ths of an inch, by standing in the same manner, in time was perfectly absorb'd.

In the prosecutions, now, of these Experiments, I could not help being surprized, when I observed how small a part of the Surface of the Water was come at by the Air, collected into a Bubble on the upper part of it; and yet saw, at the same time, that all that Air insinuated itself by so small a part of the Surface throughout the whole body of Water, out of which it had before been drawn. And doubtless, it had then distributed itself equally, throughout all the interstices of the whole Water. There must necessarily, therefore, be in Water, a certain attracting, imbibing power, in respect of that Air, thus drawn from so little Space, through all its parts; for this Air stands in no need of concussion to force it into the Water; let it but alone, and it will make its way in of its own accord.

The illustrious *Stairs*, in his very elaborate Philosophical Works, was induced by many reasons to be of opinion, that there never was any true Air in Water, and that those Bubbles produced from Water, in the Air-pump, did not arise from true elastic Air; but that in Water there always reside little active Fires, which making their way through the Water, when this is freed from the pressure of the Atmosphere, and by their levity tending upwards, form those little Bubbles which presently burst asunder. I am apt to believe, however, if that worthy Gentleman, whose candour and virtue are every where spoke well of, had sufficiently considered these last Experiments, he would have been of another opinion: For then, in these collected Bubbles, thus produced, he would have found all the true characters of pure Air. See *Stair's Philosoph. Experim.* p. 572. Let these things suffice then, touching the first method of separating elastic Air from Water, by removing the compressing weight.

EXPERIMENT VI.

It is very entertaining to see the manner in which Fire separates this Air from Water, and to observe this Air, when it is thus separated, and collected together, which is very easily performed by the following curious Experiment. Take a large wide Vessel AB, able to bear the Fire, let the bottom of it be flat and plain, and let it be filled with common Water. Then let there be put in this Vessel, a Funnel, so large, that the broadest part of it may nearly cover the bottom; and let the Neck of the Funnel CD be wholly immersed under the surface of Water contained in the Vessel AB. Let there then be provided a little glass Bolthead or Vial EF, the mouth of which is wide enough to admit the Neck of the Funnel. I now fill this Vial up to the top with Water, and having stopt the Mouth of it close, with my Finger, I invert it, and thus let it down into the Water in the Vessel AB, so that no Air at all can get up into it; and then, as you see, I put the Mouth of the Vial E over the neck of the Funnel CD. This done, I put the Vessel AB with all its Apparatus upon the Fire, so that the whole may grow hot gradually, and at length the Water in the Vessel AB may boil briskly. And when this is the case, then the Water of the Vessel boiling under the Funnel, will determine the Air of the Water, which is now formed into Bubbles and tends upwards, through the Funnel into the Neck of the Vial, and thence into its Belly, and so collect it together in the upper part F. This then being continued for some time, there will at the top F be contained true Air thus separated from the Water which boiled under the Funnel in the Vessel AB. And this Air, again, will have a perfectly elastic quality,

It extends itself from a small space through the whole Body of the Water.

These Bubbles do not proceed from Fire.

Air is separated from Water by boiling.

Fig. 3.

quality, and can be drawn out of the Water only in a certain and determined quantity, beyond which no more Air can be procured, how long soever the boiling is continued. In this Experiment, now, there occurs a *Phænomenon* that is pretty remarkable; for when the boiling Water has thus sent up in Bubbles all its contained Air to F, there nevertheless, in the course of the boiling, are produced other Bubbles, with a sudden and considerable *impetus*, which bursting with a great force, shake the Water and Vessels, but do not by this means produce any Air. These Bubbles, therefore, arise not from Air, but from the Fire which acts in the Water. These therefore continue to the end, tho' you boil the Water ever so long; whereas the aerial Bubbles are quickly over: These likewise are large; whereas the Air-ones are but small: These burst asunder with an *impetus* like that of Wind; whilst the others discharge themselves very quietly: Nor do these, as I observed before, generate any Air, though so exceeding large. And for this reason the excellent *Mariotte* gives to these Bubbles the name of Fulminations. And if the famous *Stairs*, in the Place above cited, means these Bubbles, he is so far in the right. These things, then, being done, and the Air being collected at F, if the whole *Apparatus* is set again in the cold, the generated Air will return into its proper Water, out of which it was exhausted. Having gone through this Experiment, with the success I have now told you, I had a mind to prosecute this inquiry farther. Accordingly I took Rain-water, and kept it boiling very briskly, for the space of two hours. This Water I then placed, boiling hot, with the *Apparatus* of the 4th Experiment, under the Bell, and drew out the Air, as carefully as I could; and at that time, no Air was produced in the upper part of the Belly of the Bottle. Afterwards, however, having thus kept the Water in this *Vacuum* for some days, there arose from it at last a pretty large quantity of Air. Surprized at this event, I was in doubt, whether, perhaps, the very Water was not transmuted into Air, by remaining so long in *Vacuo*? Or whether the Air was not so intimately mixed with the Water, that it could not be intirely expelled by boiling; though by the Water's being thus left in *vacuo*, it might, by length of time, have thus slowly disengaged itself from it?

EXPERIMENT VII.

Air is separated from Water by Frost.

I took some Rain-water, and put it in a very diverging, conical, glass Vessel, and then exposed it in a hard Frost. Some time after the Particles of the Water began to be constringed by the Cold, though it is not possible to condense it by the pressures of the greatest weights. But when the Particles of the frozen Water, thus more closely contracted, begin to lessen the little Spaces intercepted between them, the Elements of the Air, which before were lodged in them, being now pressed out of 'em, become united with one another; and by this means, while these elastic Elements, which before existed separately, come into mutual contacts, they seem, by their reciprocal repulsive force, to acquire an Elasticity, which they had not while they were apart from one another. Hence then, little Bubbles begin to be generated, which grow larger and larger, increase in number, become at length of a considerable size, and tending upwards, and being lock'd up within the hard Ice, remove it by means of their Elasticity, and, notwithstanding its hardness, make it swell out on every side, and by this means break asunder the Vessel that contains it. And here we observe, that

that the harder and longer it freezes, the greater, always, more numerous, and so much the stronger, likewise, are these aerial, elastic Bubbles. Hence it comes to pass, that Water seems to increase in magnitude by Cold; whereas, in reality, the Ice itself is less than the Water was; but these Bubbles of Air, thus generated, whilst they form within the Ice pretty large Spaces, where there is no Ice at all, must necessarily increase its dimensions; and by this means, likewise, they acquire that prodigious power by which they become capable of splitting the Vessels in which they are confined. If, therefore, the Frost is very sharp, and of a very long continuance, then all the Air, before distributed through the whole body of Water, extricates itself from the pores of the Ice, is united into those icy Bubbles, and disengaged from the Water. This then is another, and new method, by which Air is separated from Water.

EXPERIMENT VIII.

Whilst Oil of Tartar *per Deliquium* is prepared from the Water diffused through the Air, one would readily believe, that this frothy ponderous Liquor must be full of elastic Air; and yet upon examination in the manner just described in the preceding Experiments, it evidently appears, that whether the pressure of the Atmosphere is taken off of it, is boiled at the Fire, or constricted by Cold, this Liquor will afford no Air at all. Hence therefore we learn, that a fixed alkaline Salt, whilst it insinuates itself into Water, expels the Elements of Air which are lodged there, and takes possession itself of those little vacuities, and thus constitutes a Fluid which is the heaviest of all we are acquainted with, except Mercury, being in weight to Water, as 7 is to 5. See *Boyle's Mech. Exper.* p. 26, 27. Or rather, don't it fix the Air?

Air is separated from Water by an Alkali.

EXPERIMENT IX.

The following Experiment concerns both the Chemist, Mechanic, and Physician, and therefore deserves their attention. I took the Urine of a very hearty Man, made in the morning, after he had his full Sleep, and whilst he was fasting, and put it into a Glass Vessel that was warmed to the same degree of Heat as is observed in a Man in health. This Vessel and Urine, the very moment it was discharged from the Body of the Man, I put upon the Air-pump, under a glass Bell, and drew out the Air as fast as I could; and yet, for a long time, I perceived no sign of any Bubbles of Air in this Urine, though it was so warm. I imagined, therefore, that there was no Air in Urine that could be shewn by this Experiment. And since this Urine was 90 degrees hot, and the Air was exhausted to 26 inches, and yet there did not appear the least sign of any ebullition, would not any other person have been of the same opinion? When I had drawn the Air out however to 27 inches, then some Bubbles began to arise; and as I proceeded to draw out more, all on a sudden, the Urine in this *vacuum* began to boil with so much violence, as it never boils in a Vessel upon the open Fire. At the sight of this I confess I was very much surprized: For whence could proceed so sudden, and so violent an agitation in a Liquor which was before so quiet? How comes it to pass, that the very little portion of elastic Air, which was exhausted at last, should (after it had born the Atmosphere's being removed to 27 inches, without any ebullition) at once produce such a prodigious alteration? Did this sudden alteration arise from the Air of the

Air out of a hot animal Liquor.

the Urine, or from the Fire then residing in it, or from both together? Many other Experiments of this kind I made with various animal Fluids, with very strong *Lixiviums* of Sea Salt, *Sal. Gem.*, Salt of Nitre, *Sal-Ammoniac*, volatile, alkaline *Sal-Ammoniac*, and with Mercury. If you would do the same, you would not at all think your time ill spent. To enter into a particular account of these things, would be tedious both to you and myself.

COROL. 1.

Elastic Air, therefore, notwithstanding its Particles adhere to one another, with some kind of tenacity, dissolves itself into its minutest Elements, that it may spontaneously insinuate itself into the vacuities of Liquids that are void of Air, and so disperse itself throughout their whole mass. That Air, therefore, is drawn into those Liquids, and those little Spaces.

COROL. 2.

And the Air so attracted into the Interstices, between the Elements of Liquids void of Air, is in that very action dissolved into its least parts; inasmuch as it is distributed through the large body of the whole Liquid.

COROL. 3.

But the quantity of Air, which after this manner is imbibed by Liquids, and distributed through their whole large Masses, is very little in quantity, and takes up but a very little room in those Liquids.

COROL. 4.

And when those Liquids, of whatsoever kind they be, are once saturated with that small portion of Air that they have imbibed, they will then receive no more of that Air afterwards, whatever art, motion, or compressing force is used to effect it; but they reject the Air, which is then super-added, repelling it from them in Bubbles or Froth.

COROL. 5.

But Liquids also, particularly aqueous ones, when they are perfectly saturated with certain Salts, will not dissolve any Air after this manner.

COROL. 6.

One Particle of Air thus dissolved, when it exists separately in the Interstices, which remain between the contiguous Elements of Liquids, does not seem to be Air, as Air is described by its physical marks. For one such intercepted particle, so long as it remains alone, within the Elements of Water which surround it, and by this means cannot touch such another like Particle, does not appear to be elastic; for this is not evinced by any Experiment. Nor, besides, is such a single Particle so easily dilatable by Heat, inasmuch as it requires a pretty considerable one before it begins to make its way out of its Liquid. Nay farther, though the Mercury in the Barometer descends 25 inches, such a Particle does not extricate itself out of the Water. As therefore one Magnet, by itself, in respect of another Magnet at a distance, would not effect any magnetical Operations, and could hardly in this circumstance be said to be a Magnet;

Magnet; so in the same manner may we conceive of the Particles of Air: But as this Magnet, when it is brought so near the other, as to be within the sphere of its activity, immediately discovers its virtues; just so again it happens with the ultimate Particles of elastic Air.

COROL. 7.

But when two such ultimate Elements of Air are by any cause whatsoever forced out of their little watery Receptacles, and so united as perfectly to touch one another, they then seem immediately to exert a reciprocal repulsive force, and thus at last to form a Bubble of the very smallest size.

COROL. 8.

This little Bubble then, which is the least possible one, as it consists only of two Particles, acquires again all the qualities of elastic Air abovementioned. And this which is generated at the very bottom of the Liquid, as it tends upwards, passes through the Interstices left between its Elements, where meeting with other single Particles of Air, it unites with them, and by this means forms a larger Bubble; and this likewise still tending upwards, and joining itself in like manner to other Particles all the way from the bottom to the top, is always the less pressed, the nearer it approaches to the Surface of the Liquid.

COROL. 9.

From what has been advanced, it seems likewise to follow, that Salts are less attractive of this elastic Air, than Liquids are, especially aqueous ones.

COROL. 10.

In every Liquid hitherto known, there seems to be contained one certain determined portion of Air; always, indeed, a very small one, but very different in different Liquids.

COROL. 11.

Hence it may be questioned, whether that Air, which in the juices of Vegetables produces the mighty effect of fermentation, is, in reality, that Air which exists in single Particles in their smallest Pores? Or rather, whether that united and truly elastic Air, is not contained in the Air-pipes discovered by *Malpighi*, and called their Wind-pipes? Or lastly, whether it is not the external Air, which commonly intermixes itself with these fermentable vegetables, during the stirring and working them about?

COROL. 12.

The elastic Air, which is divided into its minutest parts, and is thus contained in the Fluids of Animals, does not seem to be the cause of the putrefaction which they are spontaneously disposed to; because, without the admission of the external Air, they are hardly brought to putrefaction; but when this is let in upon them, they putrefy immediately.

EXPERIMENT X.

The quantity of Air in Water, is greater than the Water itself.
Pl. VIII.
Fig. 4.

This elementary elastic Air, which is thus divided into its smallest parts, and dissolved and dispersed through Water, seems there to take up but a very little room, which does not fall under the observation of our Senses: And yet, when it is drawn out of the Water, and collected into one space, it then takes up a larger compass, than all the Water does out of which it was exhausted. The truth of this paradox is exhibited to the Eye by the following very elegant Experiment. Take a parallelopipedal Vessel AB made of Copper. At the bottom let there be made a very little impression or cavity C, big enough only to hold a drop or two of Water; let there be provided likewise a very small conoidal glass Vessel D, open at the base, like a common Thimble; by which name I shall here call it. Let then the Vessel AB be filled so high with very pure expressed Oil, that the Thimble D standing at the bottom of the Vessel AB, may be quite covered. This done, let the Thimble be laid upon its side as in F, so that there may be no Air at all in it, but that by this position, it may be quite full of Oil. These things being thus disposed, let the Vessel with the Oil and Thimble be set on the Fire, that the Oil in the Vessel, and consequently in the Thimble, may boil; and let the boiling be continued, till the crackling noise of the Oil is quite over. By this means, then, the Air, and Water, which happened to be in the Oil, or about the sides of the Vessel, or the Thimble, will be intirely expelled, and the Oil will be totally freed both from Water and Air. This done, take the Vessel off of the Fire, and let every thing in this situation stand to cool; and then, let a drop of Water, by means of a little glass Pipe, be convey'd through the Oil into the little cavity C, which by means of its own weight, will be kept there under the Oil. Then let the little glass Vessel D, keeping it always under the Oil, lest any Air should get into it, be placed with due caution erect over the little cavity C, so that the middle of its open Base may be very exactly over the drop. By this means then, as very evidently appears, the Thimble will be quite full of Oil, all Air and Water being excluded. This duly performed, let the Vessel AB, with its *apparatus*, be so placed upon a stand, that the Flame of a Candle may be commodiously applied to the little convexity, at the bottom of the Vessel, in the hollow of which is lodg'd the drop of Water. Let then the Flame be applied to that part, but in such a manner, that the drop of Water may not be made hot at once, but very gradually. The drop then heated in this manner, and at length boiling, will produce a wonderful crackling noise, and being under the Thimble, or little glass Vessel, and kept down by the Oil, will discharge itself of its Air into the upper part of the Thimble, where it will take up a very large space while the Heat is continued, and will proportionably drive out the Oil; and the motion of this little crackling drop, will often be so great, as to lift up the whole Thimble. When at length, by this method, all the Air is expelled out of this little drop of Water, let the whole stand and cool. The Air then in the little glass Vessel growing cool, will be pressed into a Bubble, collected at the top of it, and appear of a greater bulk than the drop of Water out of which it was thus drawn. When you are perfectly satisfy'd of this, let the whole *apparatus* be put under a glass Bell on the Air-pump, and let the Air be exhausted; and you will

will then see how that Bubble of Air in the upper part of the Glass will expand itself, and drive out the Oil, and thus evidently demonstrate a true aerial elasticity upon the removal of the compressing Atmosphere, as it did before upon the augmentation of the Heat: But as soon as ever you let in the Air again, the Bubble will be reduced to its former size; so that you cannot doubt, but that the Air, which is generated by this Experiment, is true elastic Air.

From this Experiment, therefore, we learn with the greatest certainty, that Air, whilst it is dissolved in Water, is by no means such a Liquid, now its Elements are thus divided, as the same Air constitutes, when it is drawn out of the Water, collected, and has its elastic Particles united into one Bubble.

Air, whilst
in Water, is
not Air.

And it is farther certain, that the Air which lies concealed in Liquids, has not, there, those physical virtues, which it possesses, when it is united out of them: So that it will never perform the same Operations in both these circumstances. Those Gentlemen, therefore, appear not to reason so justly, who, after they knew that Air might be procured from Liquids, have concluded, that the Air, whilst it remained in those Liquids, had there all the active force, which it discovered when it was drawn out of them. But in this affair indeed, almost all Authors, even Men of great penetration, have been deceived. Of this let the great *Borelli* be an instance, in his very excellent Treatise of Animal Motion, where he talks of a vital oscillation of elastic Air in the Blood. Warn'd therefore by these Examples, let us learn to reason cautiously, and prudently, lest at any time we should be refuted by our own Experiments. But here again, we discover another wonderful Paradox, and that is, that the elastic Particles of the Air, while they exist separately, and apart from one another, take up a less space, than the whole of them possess, when they are collected into one Body.

Nor does it
act like Air.

The power therefore which the Air has of expanding itself into larger spaces, arises from the approach of its Particles nearer to one another. Do they then, when they are very nearly united, repel and fly back from one another? This was the opinion of the incomparable *Newton*, and the continual advances that are made in experimental Philosophy, make it every day more and more probable.

The elasticity
of the
Air,
owing to the
union of its
Elements.

Now, from our Doctrine of the nature of the elasticity of the Air, we learn, that Air, when it exists in single distinct Elements, can make its way through very small passages: For Water, which always of itself contains a certain portion of divided Air, will pass, together with its own Air, through every thing, through which it can itself naturally make its way. This appears evident from the Experiments upon Animals, Vegetables, and even upon Fossils; since in the Water drawn out of all these, there is always elemental elastic Air. For this reason, therefore, such Air cannot be excluded those places, into which the Liquids which conceal it can enter: And hence elastic Air, in this sense, disperses itself through Bodies very extensively.

The elastic
parts are ve-
ry penetra-
ting.

But now, when these aerial Elements are united, and constitute a part of the common Air, they will not then make their way through those *Meatus's* into which they could easily insinuate themselves, when they were intermixed with Liquids. Nor will the smallest bubble of Air be able to pass through those places through which a Liquid with its Air would be admitted. And farther,

Air itself is
not very pe-
netrating.

these Elements of Air can hardly by any means be made to pass through Liquids, which are already saturated with Air, tho' at the same time they will spontaneously, and very quickly insinuate themselves into those that are void of it.

For these reasons, then, at length, we may perhaps fairly conclude, that it is nearly true in general, that Air, whilst it is distributed through, and intermix'd with Liquids, does not act in those Liquids, with any power which is ordinarily ascribed to the common Air. For it appears from Hydrostaticks, that when a very deep Vessel is filled with any Liquid, the pressures of the Liquid at different depths, are as those depths, or the distances from the upper Surface. At the bottom, therefore, in this case, the pressure will be greatest of all; at the top very inconsiderable: And yet the Air in that Liquid, so long as it remains divided into its Elements, gives no manner of indication of this diversity of pressure; since it neither appears below in a greater quantity, nor above in a less; nor does it spontaneously pass out at top; nor in *vacuo* do the Bubbles appear to be generated in the upper part. But as soon as the Air, by the means abovementioned, begins to be separated from the Liquid in which it is contained, it immediately puts on the nature of true Air, and acquires all its properties. In the Chyle, therefore, the Milk, Blood, *Serum*, *Saliva*, Bile, Pancreatic Juice, and Urine of Animals, there is naturally Air; but Air that is dissolved after this manner into its distinct Elements, and therefore in that state, does not act as Air. And as it has already appeared from some former Experiments, that this Air, whilst it is divided into its Elements in the Pores of Liquids, is not able to disengage itself thence by the assistance of any alteration of the Atmosphere, which naturally happens, even tho' the Liquids are heated to 92 degrees, which is the greatest Heat of a healthy Person: Hence it follows, that the Air which is distributed through the Humours of a living human Body, cannot naturally extricate itself from them in such a manner, as to collect itself within our Vessels in form of aerial Bubbles, and thus produce there the effects of true Air. And it at any time this should be the case, as the famous *Ruyfch* makes mention, who found the Heart in a dead Body distended with an aerial *Flatus*, and as *Hippocrates* intimates, in his Treatise *De Flatibus*, where he supposes such flatulencies to happen in the Blood-Vessels, it presently becomes fatal; as has long ago appeared to be true by some anatomical accounts of Injections. See *Harderi Apiarium*, p. 114. and many other Authors, who have made the same Experiments, and always with the same success. From these Observations, therefore, which are undeniably true, we may see what we ought to think of that Doctrine which has been laid down by very famous Men, concerning the mixture of the Air with the Blood and other Fluids, and the continual return of it from them again.

Air produced
from Crabs-
eyes and Vi-
negar.

It now remains in the last place, that by a few other Experiments which I shall make before you, we examine into some other Methods, by which elastic Air may be produced from Bodies, in which it before lay concealed. For this purpose, I have so prepared my Air-pump, as to be able at pleasure, to mix Bodies together in *vacuo*, which by proper contrivances, you will see, I shall be able to do very conveniently. You see here then, the whole Machine duly fitted up. Under this glass Bell, there is as perfect a *Boylean Vacuum*, as by pumping I was able to procure. In the barometrical Tube affix'd to the Pump,

Pump, to serve as an *Index* to the *Vacuum* produced, the Mercury stands at the height of twenty-eight inches and a half. In the little glass Vessel under the Bell, there is a drachm and a half of whole Crabs-eyes. On these now I pour in *vacuo* an ounce and a half of distill'd Vinegar, which being warm, the greatest part of its Air is thereby drawn out, as the Air is out of the whole Bell: And you see now, as soon as I have poured in the Vinegar, there arises an incredible ebullition in the glass Vessel; and immediately the Mercury in the barometrical Index descends, and that at such a rate, that in the space of half an hour, it sinks twelve inches. This Receiver, out of which the Air is drawn, and under which this Experiment is performed, will hold seven pounds and two ounces of Water; and the Thermometer at this time stands at the degree 52. Hence, therefore, it follows, that there is here produced a quantity of Air which fills a space capable of holding 114 ounces of Water, which Air is in density to the common Air, as 12 to $28\frac{1}{2}$, or as 24 to 57; and consequently, if the Air here generated was reduced into a space capable of containing but 48 ounces of Water, which is 81 cubic inches, supposing a cubic foot of Water to weigh 64 pounds, then this Air thus contracted, would be in *equilibrio* with the whole Atmosphere. And by the way, in this Experiment you have observed in the first place, that this ebullition is much brisker in *vacuo*, than under the weight of the whole open Air; and that therefore, the pressure of the Vinegar upon the Crabs-eyes is not requisite to this agitation: In the second place, that so much elastic Air is produced from these Bodies thus mix'd together, as fills up the space of 81 cubic inches; and such Air too, as by its elastic power is able to resist the pressure of the whole Atmosphere: In the third place, that this surprizing quantity of Air can lie concealed in these Bodies, so as not to discover itself in any manner, till this effervescence has disengaged it from its confinement: In the fourth place, that hence it is exceeding probable, that the elastic Air thus produced here, has no weight, as the common Air has which is filled with Vapours. In the fifth place, we hence discover, what would be the consequence, should an Absorbent like Crabs-eyes, an Acid like Spirit of Vinegar, and a *Vacuum* ever happen to meet together in the Vessels of a human Body: For which reason alone, we begin to suspect, that Effervescencies of this kind cannot be brought about in our Vessels, since they would hereby produce such a quantity of Air; whereas a little Air in the Veins becomes fatal. And in the last place, it hence appears, that a *Vacuum* within us would be of vastly dangerous consequence.

After I had made this Experiment, I took a drachm of Chalk, and poured upon it in this *vacuo* two ounces of distilled Vinegar; upon which there arose a more violent Effervescence, nay an exceeding violent one, much stronger than in the open Air. The whole *Apparatus* being the same, the Mercury in the Index fell from $28\frac{1}{2}$, to 6 inches: So that the generated Air reduced to the density of the external, would fill up a space capable of containing 90 ounces of Water; and consequently, the space of 151 cubic inches.

But again observe, if you please, this Experiment, while I pour, in *vacuo*, Oil of Tartar *per deliquium* upon distilled Vinegar; what a sudden and violent ebullition is hence produced! and yet when we mix these two Liquids in the common Air, there is at first hardly any agitation discernible by our senses; as you yourselves have so often seen, whilst I have prepared before you the purging.

From Vinegar and Chalk.

From Oil of Tartar *per deliquium*, and Vinegar.

purging Salt of *Sennertus*. This, therefore, you will again take notice of, with regard to the difference of an Effervescence produced *in vacuo*, or in the common Air. But what a large quantity of Air is here suddenly generated? and yet you remember, that upon examination of Oil of Tartar *per deliquium*, it did not discover any: And you know likewise, from the Observations of Mr. *Homburg*, that Vinegar is saturated with a very small quantity of the Alkali of Tartar; namely, with one 14th part. *Hist. de l' Acad. Roy. des Scien. T. I. p. 52.* Notwithstanding which, however, they are capable of producing so much Air. What mischief therefore would follow in a human Body, if such a *Vacuum* should ever happen there, with the like Effervescencies in it! But *in pleno*, as is evident, these Effervescencies would be far less dangerous. How plainly, likewise, do we discover, that the pressure of the Atmosphere, in order to apply and force these Bodies to one another, is not at all requisite to the producing these Effervescencies; since we see by Experiment, that on the contrary, they are more impeded and restrained by it. They rather arise, therefore, from some peculiar innate power in these effervescent Bodies, which is the cause of all this their motion even in *vacuo*. And here, farther, we observe, that by means of such Effervescencies, the Air which was in the Bodies before the Effervescence, is disengaged, and separated from them.

From Oil of
Tartar and
Oil of Vi-
triol.

The Experiment which I am now going to make, is a very dangerous one, and therefore requires the most cautious management. We will try what will be the consequence of mixing the best Oil of Vitriol, with the strongest Oil of Tartar *per deliquium* in *vacuo*: And since we learn from the Observations of Mr. *Homburg*, in the place last cited, that eight parts of the best dry Salt of Tartar will be saturated with 5 parts of Oil of Vitriol, I shall here make use of that proportion. We know very well now, that in the open Air, an incredible ebullition arises from the mixture of these Bodies; and therefore, in the first place, I shall endeavour, as much as possible, to draw out all the Air that is contained in these Liquids, that the aerial expansion may afterwards be so much the more moderate. And for the same reason, likewise, I have chosen for this Experiment, a Vessel twenty times bigger than would be necessary to contain these Liquors not expanded; for there is danger, lest by the ebullition that arises *in vacuo*, it should be burst asunder. And this Vessel likewise, in which this Effervescence is to be excited, should be set on a large flat glazed Plate, lest the acrid Liquor, which would corrode the Brass, should run over and damage the Pump. With these cautions, then, I thus perform the Experiment. You see here under the Bell, upon the Air-pump, these two glass Vessels, in one of which is the Oil of Vitriol, in the other the Oil of Tartar *per deliquium*. In the first place, then, I draw out all the Air that can be exhausted by the Pump. Whilst this is doing, you plainly see, that no Air at all is come out of the Oil of Tartar, nor so much as one little Bubble is produced in it. But on the other hand, having now exhausted a great deal of Air, you perceive that abundance of Air arises from the Oil of Vitriol, and continues to pass out of it for a considerable time; for great numbers of large Bubbles are here generated, which as you hear, make a considerable noise. I leave now this Oil of Tartar, and Vitriol *in vacuo*, for the whole space of fifteen hours, that I may, as much as possible, extract all their Air from them. After then they have stood thus long, I mix this Oil of Tartar and Vitriol together,

gether, both, as any one would imagine, void of Air; and what is the consequence? Why there arises, in an instant, the most violent Effervescence; such a one as every way disperses the conflicting Particles through the whole Bell, and throws them upwards with an incredible force. But to what a prodigious degree at the same time does the rarefaction of these Liquors thus mix'd together extend itself. Certainly, they are expanded to far more than twelve times their former bulk, so that if we had not been cautious in chusing a large Vessel, they would have run over the Brim of it. Here now we made use only of * four drachms of Oil of Tartar, and a drachm and a half of Oil of Vitriol; out of these too, all the Air was exhausted; no Air appeared at all, except only in the Oil of Vitriol; and yet the Air produced by this Effervescence, has depressed the Mercury from 29 inches to 12 $\frac{1}{2}$. Hence, therefore, it appears very clearly, that all the elastic Air, which is contained in Fluids, cannot be drawn out of them by means of the Air-pump, but only so much of it as can extricate itself when it is quite freed from the pressure of the Atmosphere; whilst in the mean time another part of it, and that much the greatest, is so closely united with them, that it cannot be separated in this manner, but may be procured from them by means of this Effervescence. The action of the pneumatic Machine in this affair, therefore, is very much limited; and hence any body would be deceived, who should imagine, that Fluids would be exhausted of all their Air, by letting them stand 24 hours *in vacuo*. If again, we carefully consider all these things together, that have been here proposed, we may almost venture to conclude, that the Effervescencies, which happen in this manner, between Acids and Alkali's, arise principally from the prodigious reciprocal attraction which there is between these Salts, by which, when they are placed at a certain distance from one another, they rush together with a mighty force, and by this means expel those Corpuscles which lie in the middle between them, and hinder their coming into an intimate union with one another. Supposing this then to be the case, then by the violent excussion of these aerial Particles effected in the very act of adunation, the elastic Particles of Air, here disposed, would be expell'd, which uniting with other like Particles, might produce the ebullition, agitation, and hissing noise, arising here from the continual disjunctions of these little crackling Bubbles. And then all the violent motion that is produced during the Effervescence, would not be owing to the mutual repulsion of these Salts, but rather to their reciprocal efforts towards a union. And for this reason it seems to happen, that all this agitation is intirely at an end, as soon as ever this adunation is perfectly compleated; whereas, so long as there remain any Salts not united, so long there likewise remains an Effervescence. In this Experiment we see likewise, that the Water is forced out of the interstices, which were between the Acid, and the alkaline Salts; for the Oil of Tartar, and the Oil of Vitriol, were both of them liquid before their mixture; but after they had been mixed together, and had undergone a violent ebullition, there was produced, by this union of their Particles, a white solid Salt in the middle of the Water that was forced out, and an aqueous Fluid impregnated with a little dissolved Salt, swam at the top. It must, however, be confessed, that the Salts so generated by the union of the Acid and Alkali, in

* This is only in the proportion of 8 to 3, not 8 to 5, as is mentioned in the beginning of the Experiment: These, however, our Author thinks, are the quantities he made use of.

this Effervescence, still contain Air, which is wonderfully elastic, and discovers itself plainly enough in other Experiments. For Sea-Salt, Nitre, and vitriolated Tartar, thus regenerated from their proper acids in the Alkali of Tartar, if they are mixed with Bole again, and distilled in an open Fire into their proper acid Liquids, produce a large quantity of a very elastic *Flatus*, which sometimes bursts asunder very large and strong Vessels. And hence, to persons who have frequently reflected upon these things, the nature of that violent and irrestrainable *Halitus*, or Vapour, which *Helmont* the Elder called, the *Gas Sylvestre*, has always appeared very wonderful; and it has sometimes been doubted, whether all that might be thus generated, would be so far of the same nature, as that it ought to be called by the same name of elastic Air? Or on the other hand, whether Bodies being resolved after a certain manner into their minute parts, might not have their nature altered, and, by a real transmutation, be changed into this elastic Air, which afterwards, being again concreted with other things, might produce new solid Bodies? And consequently, whether, besides the common elastic Air, there was not in nature something else very much resembling it, and yet not perfectly the same.

From Spirit
of Nitre and
Iron.

But to return to our Experiments. Please to observe, then, I put under the Bell, with the same caution as before, a Glass, with very strong Spirit of Nitre, and then exhaust the Air as carefully as possible, and you see now, which is surprizing, that this Spirit of Nitre, though all the Air is exhausted, scarcely causes any ebullition *in vacuo*, neither did it whilst the Air was drawing out; whereas, in the former Experiment, Oil of Vitriol, which is more acid than Spirit of Nitre, yielded, from the same cause, a large quantity of Air. There seems, therefore, something extraordinary to obtain in this case, which appears to be still so much more wonderful, as Spirit of Nitre, as soon as ever the Vessel is open, and the Air comes at it, emits very volatile Fumes, and those pretty active ones too; whereas pure Oil of Vitriol, in the open Air remains without any such alteration. Let the cause, however, of this *Phænomenon* be what it will, let us see now what will be the consequence of throwing into this Spirit of Nitre, thus *in vacuo*, a grain or two of the Filings of Iron. You see, then, what an enormous ebullition is hence produced, and what a quantity of very red, dense Fumes diffuse themselves through the whole Receiver. And at the same time observe, what an incredible swelling and puffing up there is of so small a matter, now it is thus rarefied, together with an explosive Fulmination, so strong, as to make one afraid, that the Vessels would burst asunder. But what is most of all remarkable in this Experiment is this, that there is indeed an elastic Air immediately generated, but yet not with that power of depressing the Mercury, nor consequently in such plenty, as seems to answer to so great an ebullition, so violent a fulmination, and to such dense, red, and agitated Fumes. But you observe, now, every thing grows quiet the very instant I let in the Air, and the mass is no longer inflated, but reduced almost to nothing. Thus then, Gentlemen, you have seen two Experiments, by which it has appeared, that the greatest and most violent explosions of Bodies may happen, without a proportional concurrence or production of elastic Air; namely, the Experiment where the Water boiled in the inverted Vial, and this, where Spirit of Nitre fulminates with Iron: A circumstance certainly worth the maturest consideration.

But

But give me leave to mention yet one more Experiment, which was formerly made, nor is to be attempted again without a great deal of caution. You have an account of it in the *Philosoph. Transact.* No. 213. p. 212. and it was thus performed: Upon the Air-pump was placed a glass Bell, 6 inches wide and 8 inches high. Under this was set half a drachm of Spirit of Nitre, in a little Vessel, and a drachm of distill'd Oil of Caraway-seeds in another, and then as much Air as possible was exhausted. These Liquors were then mixed together in *vacuo*; and in an instant the whole Bell was thrown up into the Air, and the mixture was set on fire. From a drachm and a half, therefore, of Liquids, an Air was here produced, which forced up 468 pound weight, with a very great force. Nor did it by this means appear accurately, how much more weight it might have raised; since it toss'd up the whole Bell with so violent a motion. And yet all the Air which was both in the Spirit of Nitre, and the Oil of Caraway-seeds, was drawn out by means of the Air-pump. But this power, or if you will, elastic Air, was produced in an instant, without any succession of time: And since the whole Receiver that very moment was filled with Flame; hence the Air, by virtue of this Fire, being so much the more expanded, acquired so much the greater force, and thus acted both by its spring, and the rarefaction from the Heat, together. This force therefore could hardly by any method be brought to a calculation; unless, perhaps, by gradually increasing the size of the Receiver, till the column of the Atmosphere pressing upon its surface, should at last be greater than the force of the explosion should be able to elevate; for then in the last elevation, you would have the weight, which the effervescent matter would but just be able to raise, or be pretty nearly equal to. And to prevent the Bell's being broke by its rising and falling down again, there may be fasten'd a cord to the top of it, which running over a Pulley, may be kept nearly upon the stretch, by means of a small weight hanging at the other end.

I should now inquire into the last method by which Art and Nature produce an incredible quantity of very elastic Air, called by *Van Helmont* the *Gas Sylvestre*; namely, by combustion, or an agitation caused solely by Fire. This usually obtains in fermentation, putrefaction, distillation, and combustion. But this is a very fruitful subject, and of a vast extent. The wonderful expansive force of a fermenting Vegetable appears to every one's observation, in Malt Liquor put up into Bottles before it has done working. That putrefying Substances generate a great deal of such Air, the illustrious *Boyle* has expressly demonstrated. *Van Helmont* too, before this, had informed the World, that in the distillation of crude Tartar in Vessels accurately luted, the Vessels, tho' very strong and capacious, were burst to pieces. And in the distillation of Flesh, Bones, or the Humours of Animals, managed with the utmost caution, unless there be some crack open, or the Receiver is very large, do not the Vessels burst asunder? Not to mention the distillation of Nitre, Salt, Vitriol and Alum, in which are produced an incredible quantity of elastic Vapours, which by their violence often cause the loss of the Vessels, contents, and labour, and frequently prove very dangerous to the Operator. In these different ways then, which, however, all agree in this, that they act by the assistance of Fire, it evidently appears, that this elastic Air concurs, as a pretty considerable and remarkable constituent part in the composition of almost all kinds of Bodies. Or if

From Spirit
of Nitre and
Oil of Car-
raways.

Elastic Air
produced
from Bodies
by Fire.

any one yet doubts of it, this certainly he must readily acknowledge, that by the action of Fire there is somewhat separated from every known Body, which after such separation, is fluid, elastic, compressible by Weight, and contractible by Cold, and again expanding itself by Heat, and when it is freed from the cause that compresses it. But as for that part of the Air, now, which when separated from all the rest that are mixed with it, we call the elastic part of the Air, we know nothing of it besides the properties just enumerated. By Fire, therefore, at least, elastic Air is always separated from those Bodies; and consequently, such a matter was in them before, though whilst it was lock'd up there, it did not produce the effects of Air; but as soon as ever any of its Particles are separated from them, and united with others, then it immediately returns to its former genius of elastic Air, and remains such, till it is some how or other again divided into its distinct Elements, and united with other non-aerial Particles, with which it may for a time be concealed, grow together, and form one mass: Tho' even in this state, it still so far retains its pristine nature, that it will again become perfect Air as soon as ever it is disengaged from this entanglement, and the aerial Elements come into union with one another. In all these cases, therefore, Air is immutable; becoming, after its separation from Bodies, what it was before it was united to them; and being able, when 'tis freed by resolution, to return again, by concretion, into the same Body, from which it was separated. This resolution and composition appears by no Art more clearly, than the chemical one. I should now therefore give you some instances of both kinds, as I have formerly in this Laboratory made a great many Experiments to this purpose: But having seen, and to my advantage perused, a very elaborate treatise, published about two years ago by the famous Dr. *Steph. Hales*, called *Vegetable Statics*, in the sixth chapter of which he has, with very great labour and accuracy, given an elegant account of his Experiments, which illustrate this Affair, and in short quite compleat it, I chuse rather to refer you to that work, which will give you a plain View of Nature, as discovered by Art.

Permit me now, then, Gentlemen, to put an end to this Discourse upon Air; in which I have principally endeavoured to shew, how necessary the knowledge of Natural-Philosophy is to a person who would make himself master of the chemical Art; and consequently, how necessary it is likewise to be acquainted with all the Arts by which Natural-Philosophy is promoted. Without these helps the Chemist is continually falling into errors himself, as well as deceiving others, whilst he mistakes the true causes of things, and assigns false ones in their room; whereas if he is sufficiently furnished with these, he has paved a way by which he may readily arrive at the true knowledge of Nature.

Corollaries
concerning
the Air, for
the use of
Chemists.

I shall only add, therefore, the few following Corollaries, and so conclude. In every chemical operation we are engaged in, the Bodies to be examined under their various changes, are exposed to this Air, of which we have been treating. All those Bodies therefore, and all those Operations, whilst they are directed by the Chemist, according to the rules of his Art, must at the same time undergo whatever the Air, by being applied to them, is capable of effecting upon them. When the Chemist therefore goes about to compute the effects of his Art, he must always likewise have a very particular regard to the action of the Air, and what share that has had in the Operation; which how-

ever is but very seldom, and very slightly attended to. I have subjoined therefore to every property of the Air, which we have been considering, the peculiar effects which properly depend upon it. I shall now, with your leave, repeat, in a very few words, those things which the Air performs by the concurrence of all its powers together. In the first place, then, it encompasses, is in contact with, confines, and compresses all Bodies, insinuates itself into their penetrable passages, and being received into them, it there exerts all its power, as well upon solid Bodies, as fluid ones. In the second place, being by its gravity determined upon those Bodies, and being at the same time divisible by its fluidity, whilst it thus insinuates itself by its minutest Elements, it meets with Bodies there, to a union with which it has a natural tendency, and hence unites its Elements with them, loses its Fluidity and its fluid Elasticity, and remains there closely confined, till by Effervescence, Fermentation, Putrefaction, or Fire, it is again set at liberty. In the mean time, however, by virtue of the other Particles which it contains in it, it brings about an infinite number of effects. In the third place, it performs particularly the office of intermixing Bodies very intimately with one another, whilst by such weight, and such perpetual velocity of motion, like the mechanical Pestil, it puts them in motion, and rubs, and mingles them together, producing after this manner very singular effects, not easily accomplished by any other means: This the ancient Alchemists, *Van Helmont*, in particular, was well apprized of, and made use of it to very valuable purposes; as you will see, if you consult him p. 151. § 45. 334. §. 84. and in a great many other places. And indeed if we expect to meet with the same success in a place void of Air, or where the Air, by reason of the height of the place from the Earth, is pretty light, or rare, our labour will be all in vain. How evidently does this appear in the combination of distilled Oil of Turpentine with Salt of Tartar? How easily is this performed in an open, heavy Air, whilst in very high places it is not to be effected? And in the defæcation of Salt of Tartar by the Air, the same thing appears as clearly. Of consequence, therefore, in the fourth place, it determines and applies the action of one Body to another. For all things which are heavier than the Air, are compressed by the Air, which rests upon them, and, as we observed in the last article, are moved by its motion, and intimately mixed together. Hence, therefore, if among these Bodies there are any which acquire some particular vertues by coming into contact with one another, then these vertues will by this means be excited by the Air, and discover themselves by their effects. And hence it comes to pass, that there are many dissolvents, which in the *vacuum* of Mr. Boyle hardly discover any corroding quality; though if the Air is let in upon them, it becomes manifest immediately. This Mr. Boyle himself remarks in the Filings of Copper mixed with the alkaline Spirit of *Sal-Ammoniac*, and in Vinegar applied to Copper and Iron, *in vacuo*. But it appears likewise, in almost every instance, that, by the pressure of Bodies upon one another, mechanical powers are brought into action; and that they cease again, as soon as ever this pressure is removed. A Diamond will not cut Glass, unless it be pressed against, and moved upon it. Attrition begets no Heat, if Bodies are not forcibly compressed together. This appears no where more evident, than in *Papin's Digester*. Here the Bones of an old Ox, for instance, with some Water and Air, are so closely included in a Copper Cylinder, that no Air or Water can

by any means possible make its way out. Fire is then applied till the Water boils. The Air therefore acquires a power of expanding itself proportional to the applied Heat; and so likewise does the Water. Hence the pressure of the Air and Water upon the Bones, must be exceeding great. In the mean time too, the Air and Water, within this Vessel, are moved against one another, and upon the Bones with an incredible velocity; and by this means, within a few minutes, the Bones are softened, and converted into a viscid Liquid, or into a soft, tender Mass, very readily yielding to the knife. In the *Fabrenheitian* Experiments, formerly mentioned, it appeared, that when the Atmosphere was made but one tenth part heavier, the Water immediately took in more Fire before it would boil. What, now, could be the cause of this, but the Atmosphere's pressing the parts of the Water more closely together? In the fifth place, the Air, considered all together, is the occasion that hardly any Body continues at rest; because this, by the smallest alteration of Heat, is immediately expanded or contracted, and, consequently, suffers a reciprocal oscillation: But these changes of Heat and Cold are perpetually happening; and hence there must of consequence be a perpetual agitation in the Air. This appears likewise evident, from the continual variation of its weight; for Barometers set in a very oblique position, and thus, upon the least difference in the weight of the Air running through a large Space, have been observed to be almost always in motion. But since two inches of Mercury are equal to 23,800 inches of common Air; hence, upon the smallest variation in the Barometer, the Air immediately runs through * 23,800 times the same space. As therefore the Mercury in this respect never rests at the same Altitude, we discover how much less the Atmosphere remains of the same weight. And since this Air insinuates itself between Bodies, and into their Pores, it seems certainly, with regard to these, to have the nature and power of a perpetual mover. Hence, perhaps, it comes to pass, that all the principal Operations of Nature are brought about in the common Air, but will not proceed, in an exhausted Receiver. Fermentable pasts, duly prepared, and disposed in the *vacuum* of Mr. Boyle, will not ferment there though they are acted upon by a proper Heat, but discharging their Air, remain unchanged. The parts of Animals, which very readily putrefy, being shut up in the like *vacuum*, and freed from their exhaling Air, do not afterwards putrefy, tho' they are kept warm. The same thing is likewise true in your Summer Fruits, which being set in *vacuo*, puff, emit a *Flatus*, and then remain at rest. So that the parts of Animals, Vegetables and Fossils, being here included without Air, seem to undergo very little alteration. In the sixth place, this Air seems always to contain in it such Particles as are fit, by their application and motion, to perform the office of a *Menstruum* upon all Bodies whatever: For as it contains and carries along with it almost all kinds of Bodies, in a state of solution, it can scarce possibly happen, but that by the successive application of such a variety, certain particles will be sometimes applied, which are proper, as a *Menstruum*, to dissolve every kind of Body. And in this respect it may be said to perform the office of an universal *Menstruum*.

* This in the original is 13,800. which our author says should be 23,800; but it still does not appear to me to be right; for since the specific gravity of Mercury to Air is as 11,900 to 1. supposing Water to Air as 850 to 1, and Mercury to Water as 14 to 1, hence the Air, I think, will run only 11,900 times the same space as the Mercury does. This I could not mention to the learned author, when I wrote to him first, because I did not know how he would alter the original; nor did I take notice of it afterwards, till it was too late to write to him again.

It is very certain, there is neither Metal, nor Semi-Metal, which may not, sooner or later, be dissolved in the Air, and by the Air, and converted into its proper *Calx*. Gold, indeed, Silver and Antimony, are less dissoluble there, and with more difficulty, because they are hardly dissolved, except by Mercury, Spirit of Salt, or Spirit of Nitre; but these rarely float about in the open Air; and hence it comes to pass, that these Fossils are not often dissolved there. If Gold and Silver Vessels, however, are for a considerable time exposed to the Air in a chemical Laboratory, where Spirit of Salt, or Nitre, or *Aquæ Regiæ* are preparing, these volatile Acids, very easily, so affect the polish'd Surfaces of the Metals, as to corrode them, and turn them into a *Flos*, or Mould, peculiar to each, and then into a *Calx*. In all other Bodies this dissolution happens much more frequently, as being much easier. But not only these, but an infinite number of other things may be effected, by those Corpuscles, which the Air always, or sometimes, at least, carries along with it. For by this means it discovers Bodies that before lay concealed, and conceals others that before were manifest; it makes acrid the soft, and softens the acrid; it fixes the volatile, and renders volatile the fixed; and it produces colours, and destroys them: But of these things there is no end. In short, therefore, you may learn from hence, that it often happens that the very same object, treated exactly in the same manner, shall have very different effects, if it is managed in a different Air. In every account, therefore, of chemical operations, a particular regard must be had to the Atmosphere, in which they are performed; since otherwise the event may very much deceive the operator, without his being in the least aware of it. In any chemical process it is impossible the issue should be the same in a different Air, where it happens, that the Air has any considerable influence upon it. And finally, how great the effect of the Air is, whilst it has free power of concurring with Fire towards the changing of Bodies, we have already observed in the history of Fire. Camphire melted in a Vessel upon the Fire, and so inclosed, that the Air cannot come at it, ascends, is purged of its impurities, and remains perfect Camphire, purer than it was before: But if while the Fire thus acts upon it, there is a free admission of the Air to it, it is consumed, producing a Flame, which burns even in Water, and sends forth thick, black Vapours, convertible into a very black Soot. Sulphur sublim'd by the Fire, remains always Sulphur, if the free Air cannot enter the Vessels in which the Sublimation is made: But if the Air once comes to it, it is immediately converted into Flame, and an acid Liquor. Thus then we may finish what we had to offer concerning the Air, for the service and advancement of the Chemical Art.

Of WATER.

As of all Bodies that lie continually before us, Water is the commonest, falling perpetually under the observation of our senses, and being made use of for most of the purposes of Life, hence it comes to pass, that every one is ready to imagine, that he perfectly understands its nature. Those persons, however, who have enquired into it, with the greatest care, have scarcely found any thing among natural Bodies which it is more difficult to form a right notion of. And the cause of this difficulty lies chiefly in this, that it is so exceeding hard a matter to separate Water from other Bodies, or other Bodies from Water. For this Element mixes itself with all the Substances that come under

The Nature
of Water
difficult to
be under-
stood.

under the examination of the Chemists, and resides in such a manner in the Air, in which all chemical Operations are performed, that it is scarce possible to secure any thing from it. Hartshorn, after it has been kept for half a Century, and is grown so dry, that a Stone itself is not dryer, and so hard, that it resists a File more than Iron, if it is distilled with a strong Fire in a dry Glass, will yield a Spirit; and if, according to Art, you accurately separate from this, both the Oil, and the Salt, you will procure a good deal of Water. Stones too, and Bricks, if they are reduced to powder, and exposed to the Fire, in the driest Vessels, always afford some Water; nay, to the Water, as a *Gluten* by which they are held together, they even owe their being what they are. What can be more evident than this? If fat Potters Earth is exposed a good while to the scorching Heat of the Sun, it is converted into troublesome volatile Dust, which is easily blown about with the least Wind, and never grows together again, so long as it is kept dry; and yet if you work it with Water, it becomes a ductile Paste, and when it is burnt, becomes a hard, stoney Substance. Of the Air's always containing Water, and applying it to the Bodies that are placed in it, I have treated already. The Air without all dispute is always full of Water in motion, as one may see evidently, indeed, in the following pretty Experiment. If in the summer time, when the Air is exceeding hot and dry, you expose to it a piece of Ice, just taken out of an Ice-house, there will presently appear a Vapour about it; and if you hold your hand very near it, you will then perceive a Steam betwixt that and your hand; thus both instances evidently demonstrating that the Water, which before being equally dispersed through the Air, did not appear, does now, being condensed by the Cold, discover itself in a visible form. If in the summer time you pour Water into a large Glass Vessel, that is perfectly dry on the outside, it will still continue so; but if you take $\frac{1}{3}$ of its weight of *Sal-Ammoniac*, reduced to Powder, and very dry, and mix it with the Water the whole external Surface of the Glass will be immediately covered with a Dew, which will soon run down in drops. This you understand, to be sure, arises from the Water, which before was by the summer Heat diffused through the Air, but is now by the sudden Cold forced to unite, and form a Vapour, Dew, and Water; just in the same manner as ones Breath, which does not appear in the Summer, discovers itself in the Winter in form of a Vapour. By these then, and infinite number of other instances, it is certainly demonstrated, that the Air has always Water in it, and therefore that it is impossible to keep Bodies that are placed in it free from Water. But now, if Water, is separated with so much difficulty from Air; so on the other hand, many other Bodies are not separated with less, from Water, so as to leave one sure that one has pure, simple, elementary Water. Who then will venture to affirm, that he is possessed of pure Water? Or who can pretend to show it perfectly unmixed with any thing else? Every body knows, that there are infinite numbers of Bodies, and that as well compound as simple, which may be dissolved so intimately in Water, that they shall not discover the least sign of their being there. Custom, indeed, which fixes the meaning of Words, calls the Liquor thus adulterated, Water; but certainly, in a philosophical sense, it is very far from being so. But farther, if we examine its peculiar nature yet more nicely, we shall find, that most of its properties, and that its principal ones too, it possesses in common with other Fluids, and hence again
it

it will be so much the more difficult to find out such a character of Water as shall perfectly distinguish it from every other Fluid whatever.

If a Person, however, would in a philosophical manner inquire into the nature of Water, he must have some certain character by which he may define that Water, concerning whose genius he is making his inquiry: For this, for the present, will serve to distinguish it from all other Bodies; and when afterwards all its properties are discovered, they must then be referred to the thing thus distinguished.

Its Character, however, must be found out.

Following this method, therefore, by Water we mean a Liquor, very fluid, inodorous, insipid, pellucid, and colourless, which in a certain degree of Cold, freezes into a brittle, hard, glassy Ice; for these marks every body knows point out Water. If, therefore, such a fluid as this could be readily procured perfectly free of every other Body, then the examination of Water Chemically, Hydrostatically, Hydraulically, Mechanically, and Philosophically, would be very easy; for in this case we should be absolutely sure, that whatever we discovered by these helps, would belong truly to the nature of Water, as upon supposition there would be no Body in it to which it could be referred; whereas, if there are other Bodies mixed with it, we shall be always in doubt, to which of those any property we observe belongs, and ought to be attributed.

A definition of Water.

But it is absolutely impossible ever to have Water quite by itself, because, so long as it subsists in the form of Water, it has always Fire in it, which can never leave it, nay, and is always in it in a large quantity; for as soon as ever the Fire in it is so diminished, that it comes to the degree 32 in *Fahrenheit's* Thermometer, the Water continues Water no longer, but becomes a very different Body from what it was before, that is to say, Ice. But in that degree of Cold, there remain a great many Bodies still fluid, which will congeal in a greater. Nay, if the Heat is decreased 73 degrees below this freezing point, even in that intense Cold, neither Alcohol, nor Mercury, lose their fluidity. From these Observations, therefore, it evidently appears, that a great deal of Fire is necessary to prevent its being converted into Ice. Certainly, between the state of Water just beginning to freeze, and the same made as warm as the Blood of a Man in health, there is a less number of degrees, than between the same state, and the greatest observed Cold; as in the former case there is only 58, in the latter 73.

Which is never alone, but always contains a good deal of Fire.

But all Water is constantly exposed to the Air, which enters into it in a certain quantity, as has already appeared. And there, likewise, it was observed, that the Air abounds with the Particles of, perhaps, all volatile Bodies. It is impossible, therefore, but that the Air should continually mix both itself, and its contents, with the Water, which by this means will be rendered impure, and be constantly receiving from it different Particles. This, perhaps, appears by no Experiment more evident, than by the examination of Rain Water, which comes from the upper regions, when after a long drought there happens Thunder, with very large Showers; for if the Rain-water is catch'd at such a time, it is found to abound with great variety of Bodies, as the Chemists have often taken notice.

And is rendered impure by the Air and its contents.

But this Air, when it is once got into Water, cannot easily be disengaged from it again; for if it is placed under a Receiver upon an Air-pump, you must remove almost the whole weight of the Atmosphere, before the Air will make

And almost inseparably.

make its way out in 32 degrees of Heat. And if in a middle Atmosphere, you would separate from Water the Air that is mixed with it, you must increase your Heat to 150 degrees. Hence, therefore, the greatest Heat that is naturally produced, and the lightest Atmosphere that was ever observed, tho' they conspire together, are not able to fetch Air out of common Water. Fix'd alkaline Salts, indeed, when they saturate Water, seem, perhaps, to dislodge the Air that was in it; but then, at the same time, they fill it with Salt; and if afterwards you attempt to draw the Water from them, by its passing through the Air, it is filled with it again. In the mean time, however, there is a great deal of room to believe, that the reason why Oil of Tartar *per deliquium* don't discover any Air in *vacuo*, is only, because by a very strong attraction peculiar to its nature, it retains it very tenaciously. For in boiling the strongest fix'd alcalious *Lixiviums*, in any open Vessel, I have often observed, that when they became so inspissated as to be just ready to grow dry, then at last, there diluting Water being carried off by the excessive Heat, they began to rise into a very large frothy collection of Bubbles, which unless properly provided against, would run over the sides of the Vessel in such a manner, as perhaps one shan't see in any other Liquors. This remarkable *Phænomenon*, now, seemed to me plainly to evince, that a large quantity of true Air is very strongly attracted by a fix'd, pure, dry Alkali, as soon as ever it comes out of the intense Fire, in which alone it is made, and that it unites it with itself so very powerful, that it will not afterwards suffer it to be separated from it, except, by the action of a very strong Fire, or by its attraction of something else to which it has a greater tendency, as an Acid, upon its Effervescence with which it lets go its Air. Hence again, then, it appears, how seldom there exists any Water, without being impregnated with Air, and its contents. The consideration, therefore, of these things, puts us in mind, before we pretend to reason from Experiments concerning the nature of Water, to treat distinctly of the Methods by which it may be obtained in its greatest purity, that when we have got some of this sort, and have examined it by every kind of Experiment, we may be able to come the nearer to the nature of the purest. To this purpose, therefore, let us carefully take a view of all those properties, which can by any means be observed in Water so long as it continues to be so. And as we proceed to examine all these in order, we must particularly take notice how any discovered property appears in that Water which is most simple and freest from every heterogeneous Body; for this, I conceive, is the only method by which we can come at a true knowledge of it.

The proper
weight of
Water diffi-
cult to find
out.

In the first place, then, the particular and proper weight of Water offers itself to our consideration. But to persons acquainted with these things, how difficult does it appear to find this exactly? For there are naturally in Water many things that are lighter than pure Water itself. This appears particularly in Rain-water, and that which in a chemical distillation in close Vessels rises into the Receiver. Whatever there is of fermented Alcohol mixed with either of these, it will most certainly render them lighter than if they were pure. And the Spirits likewise produced from putrified Vegetables or Animals, dispersed in the Air, and mixed with these Waters, will have the very same effect. In the mean time, however, there are many more Bodies found dispersed through Water, that are really heavier than simple Water, and which, consequently,

quently, by their admixture, render it much heavier than it is naturally. Hence Fountain, River, and Well-water, have by this means their specific gravity increased; as saline, saponaceous, and vitriolic substances are frequently mixed with them in very large quantities.

Well-water, is properly that which comes from that subterraneous *stratum*, Well-Water. which is called a (*Sabuleum scaturiens*) springing Gravel. For if you dig through the upper crust of the Earth where it is not rocky, at a certain depth you will come to a *stratum* of very pure Gravel; and if you then proceed to dig any deeper, you lose your labour, for after you have removed a quantity of Gravel, there will in a little time as much be brought again from the neighbouring parts; and hence they have called this place a springing Gravel. In this Gravel, now, the Water always rises from the bottom, and runs down from the places about it. Hence this collection of Water is called springing Water, or a Living-spring, and the Water itself (*Aqua Viva*) Living-water. If you take care now that no Water shall come into this Well, but what passes through this Gravel, then in that place the Water will be exceeding pure. For the Sand is nothing but a collection of very small clean Flints, whose figure, and size, are so various, that they can never be so disposed among one another, as not to leave little empty spaces among them: Hence the Water is always able to insinuate itself between them, tho' they intercept almost every thing else; and by this means, when it has been so filtered for a considerable time, it loses its impurities, and becomes very limpid. If there are no Salts therefore about this Gravel, this Well-water will be pure and pellucid. But if on the other hand there are any Salts, saline, or saponaceous Substances near the Spring, then these being intimately united with the Water, cannot be separated from it, by this its passage through the Gravel, but will communicate their weight to it as well as their other properties. And this, in reality, is found to be the case almost all the World over: For the Earth is the grand Chaos from which all things arise, and to which they all return again. Since, therefore, this Water by running through the Earth, becomes a *Lixivium* of all those Bodies which it meets with, and is capable of dissolving, it appears evident, how seldom this can be pure, and that it must be very different according to the place in which it is found. If you take, however, that Water that is drawn from the purest Well, and therefore is the most simple of the sort, and compare it with the purest Gold which is always exactly of the same specific gravity, then its weight to that of Gold, is found to be as 250 to 4909, or as 1 to $19\frac{5}{8}$. This you find in the *Philosophical Transactions* of the *English*, which they have confirmed by repeated Experiments. The same Water is found to be 850 times heavier than the common Air: And an *English* cubic inch, examined with the utmost care by the great Boyle, weighed 252. 256. 260 grains. *Boyl. Med. Hydrostat.* p. 110. *Act. Leipf.* 91. 196. That there should here now be this difference of 8 grains, that is near a 32d part of the whole, is not so much to be wondered at, since heat easily renders Water lighter. To fossil chrystal Water was in Weight as 1 to $2\frac{1}{2}$; to Marble as 1 to $2\frac{7}{10}$. In giving an account, however, of the comparative gravities of Bodies, we should take notice of the degree of Heat in which the Experiments were made: For as the expansion of Bodies of the same kind arising from the same Heat, are in a reciprocal proportion to their densities, Fluids, however, being more expanded than Solids; hence

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Metals

Metals are vastly less expanded by the same Heat than Water. For this reason, therefore, if the weight of Water is compared with that of Gold, or any other Metal in different degrees of Heat, the Observations will never be found to agree: But if two quantities of different Water are examined and compared with Gold in the same degree, then that which is found to be the heaviest, will always have dissolved in it some other Bodies which are heavier than the Water itself. Hence the heavier Waters are, the more they are always to be suspected of having something heterogeneous in them; and for this reason, the Physicians always condemn such Waters, as most prejudicial to health, on account of the foreign Bodies mixed with them, which are often very pernicious. There have been some Well-waters, however, found to be lighter than in the proportion abovemention'd: And these are always so much the purer, and more wholesome; except this should happen from any Spirits being mix'd with them. *Hippocrates*, in his Book *De Aere, Aquis & Locis* §. XVI. speaks of Waters that boil easiest and pass quickest. And again, §. XVI. he says, that *Rain-water, which is the lightest, sweetest, and clearest, is best for medicinal purposes*. And *Herodotus* has this passage, L. III. c. 125. *The Ethiopians live to the age of 120 years, and some of them more. Their food is boiled Flesh, and their drink Milk. They have a Water upon which nothing will swim, neither Wood, nor things that are lighter, but in it all Bodies sink to the bottom; and by means of this, they arrive to such a great age*. But where is there any such Water to be found now-a-days? Certainly no where: If there was, we might then compare our Water with it. But neither Nature or Art affords us any such thing, no not by the most careful and repeated distillation. When I formerly, therefore, read this Passage of *Herodotus*, which I absolutely believe to be true, I was induced to suppose, that the Wood in that part of *Ethiopia* was exceeding heavy, and at the same time the Water, in comparison of ours, very light. And, indeed, we know, that in *Asia, Africa, and America*, especially in the hottest parts of these Countries, there grow some sorts of Wood, which in hardness are equal to Iron, and in weight almost to Stone, and are hence called (*Sideroxyla*) Iron-Woods. Nay, how solid and heavy is our own Box, if it is but old and sound? Not to mention that sort of Oak called generally the Iron-Oak, and *Guaiacum*, if it is but good. And if we will but reflect upon that Wood in *America*, of which the Inhabitants make their weapons, we shall have no room at all to doubt, but that there were exceeding heavy Woods in those places which *Herodotus* makes mention of. And, indeed, modern Observations confirm almost every thing, which that great Man has asserted, notwithstanding some persons who have but little learning, and are unacquainted with Natural Philosophy, look upon many of them to be fabulous, and false. The lightest Water, however, that we are now-a-days acquainted with, either natural, or rendered pure by Art, is always heavier than any Wine or Beer, prepared with Water from Vegetables by Fermentation.

Fluidity of
Water.

A second property of Water, which it has in common with other Liquors, is its Fluidity; which in this is very remarkable. For it is here so great, that the ultimate Particles of Water, by a gentle Heat, or small degree of motion, will recede from one another: So that Experiments made carefully, and on purpose, have determined how much Water in a certain degree of Heat, and a given time, will exhale from a known Surface not agitated by the Wind. In which

which examination, this is particularly observed, that, *cæteris paribus*, Water exhales so much the more, as it is more pure; and so much the less, as it is the more saturated with Salt. If it is pure, therefore, it has scarcely any tenacity in its parts, which upon being drawn, do not run out in long cohering Spirals, but are divided rather into dewy Particles. And when in distillation in any clean glass Vessels, a warm watery Vapour arises with a gentle Heat, and sticks against the cooler sides of the glass head, it never runs down, and forms tenacious *striae*, like Oils and Spirits, but discovers its dissipated Particles in appearance of a fine Dew. But very salt Water, on account of the Salt and *Bitumen* mix'd with it, does not suffer its Particles to be separated so easily as sweet. Hence Fountains, Brooks, Rivers, Lakes and Ponds, send up more Water, in proportion, than the salt Sea. The exhalation of this, however, which is very considerable, has been calculated by the ingenious Dr. *Halley*: For after, with pure Water, he had mix'd $\frac{1}{40}$ th part of Sea-Salt, and thus brought it to the Saltness of the Sea, he put it into a cylindrical Vessel $7\frac{8}{10}$ inches wide, and 4 deep, and then exposing it to a degree of Heat equal to that of the hottest Summer, in a still place where there was no Wind, it exhaled 6 ounces in 24 hours; and consequently, in that space of time, it had evaporated to the thickness of $\frac{2}{5}$ ths of an inch; tho' the Water in that degree of Heat is scarce sensibly warm, and by no means emits any visible Vapour. *Phil. Transf.* N. 189. p. 366. If Water, however, is set in a close place, where the Sun never shines, nor any Wind blows through, and is kept there for a whole year, it then exhales only to the depth of 8 inches. *Halley. Ibid.* p. 183. N. 212. But I have experienced myself, as I formerly took notice, that Water being exposed to the Wind, in a cylindrical Vessel, was in a short time, by the motion of it, dissipated into the Air. This I learned, by setting a brass Vessel 8 inches high, in which there was some Water at bottom, in the open Air, and between two Walls when the Wind was very high. The ingenious *Kruquius* has observed, that the Rain, Snow, Hail and Dew, collected in the space of one year, considered as Water, rose to the height of near 30 inches, and that in the same time the same quantity exhaled from Vessels that were placed in a still shady place, but in the open Air: Hence then it appears, that by the Heat of the Sun, and the Winds, Water is perpetually carried off, dispersed, and rendered volatile, and preserved from stagnation and inspissation; and hence we see the vast service, and necessity of Winds. And again, which makes it as much as possible to our present purpose, hence we learn the great mobility of the Elements of the Water among one another, when by so light a cause, it suffers itself to be totally divided and resolv'd in its ultimate Particles.

This very great fluidity of Water, however, depends intirely, and solely upon Fire, which acting upon it in a certain degree, gives it this fluidity. For if the purest Water we are acquainted with, is so exposed to the Air, that it may be perfectly reduced to its temperature, it then loses its fluidity, when *Fahrenheit's* Thermometer is fallen to the degree 32. Three and thirty degrees, therefore, of Heat, or Fire, serve to keep Water in a state of fluidity. And so long as Water has this degree of warmth, so long it retains a motion in itself, nay and exhales too, and consequently keeps fluid by means of this Fire present in it.

Depending
solely on
Fire,

And that a
pretty confi-
derable one.

But the natural cold of a very severe Winter, was observed at *Gedanum* to decrease to the first degree in the same Thermometer, as we formerly mentioned in our History of Fire; and in a natural way, the Heat of the Air seldom increases from that degree to the degree 80; whence it appears, which is pretty surprizing, that Water, tho' exposed to more than $\frac{1}{3}$ of the greatest natural Heat, becomes and continues Ice, whilst in the remaining part only, it becomes and continues Water. This certainly, was it not demonstrated by indisputable arguments, had never been believed. In Nature, therefore, there must be some weighty reason, that makes it necessary, that Water should be Water only in that degree of Heat, and should harden into the form of Ice, as soon as ever that is diminished.

Nor can its
fluidity be
farther in-
creased.

When the fluidity of Water, now, is once produced by this determined degree of Heat, it then continues exactly the same in every farther increase of it. Nor has it been possible, by any means whatever, to render Water still more fluid, tho' you make your Fire ever so strong. Water, therefore, always exists in its most fluid state, or becomes immediately Ice, and consequently, the Fire cannot by any action divide its Elements any farther, but only removes them from one another, which being accomplished, it at once becomes as fluid as its nature permits. This again, which otherwise would have been incredible, the incomparable *Newton* has made appear by a famous Experiment; for *Pendulums* oscillating in the very coldest, and hottest Water, discovered that they met in both cases with equal resistances. *Opt.* p. 312.

This, however, must be understood, to regard those changes of Bodies only, which our senses are capable of perceiving; and here we must consider only the lubricity of the Particles of Water, which we suppose affect one another with so small a cohesion, that it cannot, by Fire, be sensibly lessened: For otherwise, we know very well, that from the 33d degree of Heat, to the 212th, Water grows continually lighter and rarer, and consequently less resisting to the motion of the same Body, supposing it to continue of the same specific gravity. This increased rarity of Water we have determined already in our History of Fire. If we suppose then, that boiling Water takes up $\frac{1}{85}$ th more space than it did before, how little difference can that make in the oscillation of a *Pendulum*, with regard to our senses? But then, besides, as the Body of the *Pendulum* too will grow hot in boiling Water, it will hence make this small difference still less sensible. And, indeed, if this was not the case, it is certain, first, that the resistance yielded by Fluids to the Bodies moved through them, depends upon the corporeal Mass of these Fluids, which is best expressed by their densities. Secondly, this resistance arises from the force with which the Particles of the Fluids, when they are at rest cohere with one another: Thus Wax, when it is cold and hard, will not transmit any Body through it, as it will when it is rendered fluid by Heat: Many expressed Oils, likewise, harden in the Cold; and even Water itself, when by its proper degree of Cold, it is frozen, loses for the future its power of letting Bodies pass through it. And thirdly, the quantity of this resistance depends likewise upon the magnitude, or smallness of those Particles, which together make up the Fluids, and into which they are at last resolved.

The Ele-
ments of
Water small.

But if we farther examine the ultimate Elements of Water, we find, that when they are singly and separately considered, they are exceeding small; and

and that to such a degree, that it has hitherto been impossible to discover their true smallness, so as to compare it with any known measure. For one of these Elements, when it is by itself, cannot, by any helps whatever, be rendered sensible; nor does it discover its size by concretion with other Bodies.

If we compare, however, the ultimate Particles of Water with those of true elastic Air, the former seem to be much more penetrating than the latter, and disposed to insinuate themselves into smaller Pores than these are capable of entering; as we have seen already in our history of Air. Does not Water pass through the invisible Pores and Interstices of Wood, which never transmit the least elastic Air? And in the *Apparatus* for pneumatical Experiments does not the Water soak through the Leather, under the edge of the Receiver; which perfectly intercepts the passage of the Air? It must be confessed, however, that this does not demonstrate the true smallness of the corporeal Mass which every such Particle contains; for here we argue only from its penetrability, which depends more upon the figure of a Particle, than its true quantity of Matter. And if this consideration is not properly attended to, we may fall perpetually into Mistakes, by reasoning from the penetrability of ultimate Elements to their true magnitude. Nor will it in this case be of greater service to us to know the weight of these Particles; for from this, likewise, we cannot pretend to conclude certainly of their size. A grain of Gold, for instance, if it is formed into a perfect Sphere, will produce a Particle that will pass through a small *meatus*; but if you beat it out into a very thin plate, and then roll it up together, with how much difficulty will it pass through a great one? But what particularly gives me reason to doubt whether the ultimate Particles of Air are not in reality less, with respect to their corporeal bulk, than those of Water, is this, that the Elements of Air may be placed in these Interstices that are left betwixt the contiguous Element of Water, without making the Water at the same time condensable; which you remember I demonstrated before in our History of Air.

Tho' we cannot however certainly determine the smallness of the Particles of Water, yet this, in the mean time, we are sure of, that there is no known Fluid, whose parts are more penetrating than those of Water; except Fire, which penetrates every thing; Magnetism, if you suppose that to act like a Fluid upon Magnets and Iron; and Light, if you will have that to be different from Fire, and at the same time to have the nature of a Fluid. Setting these aside, then, I ask the Philosophers, if they can produce any Liquor, which *cæteris paribus* will pass through any passages that are impervious to Water? I am very sensible, indeed, that Oils will sometimes soak through wooden Vessels, in which Water might be contained; but then the Oil dissolves the Oil, and Resin of the Wood, and so they both run out together; whereas the Water, not being able to dissolve the resinous oily Substances, is very well secured, just in the same manner as we see Water won't run through Paper that is well soaked in Oil, though Oil itself drops through it readily. And hence it happens, that Syrup of Sugar, though a pretty thick Liquid, will penetrate through wooden Casks that will hold Water; for Sugar diluted with Water is a *Lixivium*, which by its saponaceous quality dissolves the tenacious Substances of the Wood, which the Water cannot. Hence, too, saline *Lixiviums*, especially from fixed Alkali's, can scarcely be contained in wooden Vessels, which serve very well for pure Water.

Perhaps less
than those of
Air.

Certainly
more pene-
trating than
others.

Water. Water, then, among all simple Liquors, that we are hitherto acquainted with, is the most penetrating, and most fluid.

Tho' there
are many
Bodies thro'
which they
cannot pass.

All Metals, however, though they are beat out into thin Plates, and then formed into Vessels, will hold Water, nor suffer it to pass through their Pores: All Gems exclude it, both the more precious and the less: No known Flints transmit it: Stones that are naturally hard, and hard, heavy, rocky Substances, perfectly resist its passage though them: Sulphurs are not penetrable by it; nor any Glass hitherto known, whether made from Flint, and an Alkali, or from Metals, if it is but well united, and has no Cracks in it: Some dense, hard, heavy, resinous Woods absolutely prevent its penetrating through them; though the lax, soft, light, watery, saline ones, are not capable of containing it, but suffer it to run through them; as do likewise Pumice-Stones, and other porous, spongy Stones: Our earthen Vessels made of Clay, and burnt Bricks, common Mortar made of Sand and Lime, and that made of the *Lapis Topheus*, which vitrifies by drying, will hold Water likewise. Glass, however, which neither makes any alteration in Water, nor suffers any from it, affords us the best Vessels for keeping it. *Clavius*, the Mathematician, poured some Water into a Bolthead, and then sealed the mouth of its long neck hermetically, and marked with a Diamond the place to which the Water rose at that time; he then hung it up, and 80 years after, it was found in *Kercher's* Study, just as full as it was at first; and perhaps it is so still, tho' it is now, since the Water was first put into it, 120 years.

Tho' agitated
by Heat.

If Water is contained in a Vessel perfectly close, that will not melt when it comes to be hot, and the Water cannot pass through when it is cold purely on account of the smallness of the Pores of the Vessel; then, if it is agitated by Fire, it will still remain incapable of making its way out. This we see evidently in all our distillations made in proper Vessels: This the Experiment of *Christopher Clavius*, just mentioned, plainly evinces: This we see clearly in *Papin's* Digester, and in the *Æolipile*, which being thrown into the Fire when full of Water, confines the Vapour of the Water, though agitated with a violent *impetus*, and only transmits it through the mouth when it's open'd. I know some great Masters in the Art are of another opinion, imagining, that the very ultimate Elements of Water are attenuated by Heat; so that after a great number of distillations, they acquire so great a subtlety as to be able to transpire through the Substance of the Glass. See the famous *Stahl*, in his *Fund. Chem. Dog. & Exp.* p. 38. § 7. But what he mentions there is upon the authority of other persons; and certainly it is a very difficult matter to lute the Vessels so accurately together, that nothing shall be able to insinuate itself through the cement. *Joachim Becher*, indeed, asserts, that Water, by a great number of repeated distillations, may be brought to have a surprizing, corrosive faculty. *Statbl.* 18. p. 120. § 6. But for my own part, in the great number of Experiments I have been engaged in, I don't remember ever to have seen the least sign of any such penetrability or acrimony. In the mean time, however, I have been abundantly convinced, that there is nothing more difficult in the chemical Art, than to repeat a distillation a great many times in an Elaboratory that is hot, and full of Vapours, without losing something of what you are distilling, and having something foreign mixed with it.

But

But it has been farther observed, that Water being contained in a strong Vessel, which it was not able to penetrate, could not, by being compressed by a vast force and weight, be made to pass through its Pores, but remained totally included in it. Please to think only what a prodigious compressure there is in *Papin's Digester*, and yet not a drop of the Water is forced through. The same thing was tried formerly in the Hydraulic Machine ABCD. This consisted of a hollow Cylinder AB, made of Brass, and closely soldered up. At B only it opened into the Tube BC, which was soldered to it, and at C was produced upwards at right Angles to the height D of six feet, so that there was a free communication betwixt the Cavity AB, and that of the annexed Tube BDC. At A there was a Cock E, a little above the top of the Cylinder AF, by which you might keep in the Liquor in the Vessel AB, or let it out at pleasure. This then being open, the Vessel AB, by pouring Water in at D, was perfectly filled; after which, the Cock being turned, more Water was poured into the Tube BC, which, according to the laws of Hydrostatics, pressed the Water in AB so forcibly, that the Vessel was distended, and the Copper Plate AF was forced outwards, and raised up, though there was a great weight set upon it, and yet not one drop of Water sweated through. But when the Water came to be raised almost as high as D, then by the prodigious pressure, the soldering was burst, and the Water run out at the Cracks. From these instances then, Gentlemen, it plainly appears, that Water, though it is compressed by the greatest force, will not pass through those Pores, through which, by the fineness of its parts, it would not have insinuated itself spontaneously.

Or by pressure.

Pl. IX.
Fig. 1.

There is a plausible Experiment indeed mentioned by the *Academy del Cimento*, in their History of Experiments, p. 203, 204. which seems to make against this assertion. For a hollow metal Sphere, being perfectly filled with Water, and then accurately closed, they put it into a strong press, and upon compressing it very strongly, they observed the Water to ooze through the Pores of the Metal. But here, as a Sphere is the most capacious of all Bodies, that are isoperimetrical, it cannot, by the force of the press, be changed into any other figure, upon the incondensable Water, without the cohering parts of the Metal receding from one another, and its substance being rendered thinner; and as the Water at the same time being compressed, acts as it were like an Augre upon the Pores of the attenuated Plates, it is possible, that the metalline, elastic *Lamina* may be so distended upon the Water which is not condensable by any force, and consequently of infinite resistance, that the Water may be pressed through the Pores of the Metal, which when the pressure is over, may by its contractile force restore itself, and close up the Pores again.

We are persuaded, therefore, that as on the one hand the single Elements of Water cannot be increased by any cause, except Fire alone, which seems to exert this power universally upon all Bodies; so on the other, that they cannot be lessened but by the absence of Fire, or Cold, or which is the same thing, by being left to themselves, or freed from Fire. But this sensible diminution, now, of the Elements of Water, considered as they constitute Water, does not extend itself lower than to 32 degrees of Heat, for then Water continues Water no longer, but is converted into Ice. And that contraction of the Elements of Water, which happens after they come to be Ice, cannot be observed any longer, because the Air, being expelled by the closer adunation of those

By Cold alone they become less.

those Elements, begins to form itself into elastic bubbles, which then by their elasticity expand the Ice, more than the Cold contracts it. Hence, however, we understand a Paradox, which the Masons affirm they have often observed, viz. that cold Water soaks through walls more easily than hot. For when we were treating of the dilating power of Fire, it appeared, that Water is more condensed by Cold than Stones; so that the Pores of Stones are less contracted by the same Cold than the Elements of Water, whence it may happen, that Water, in its greatest degree of Cold, may pass through those *Meatus's* which were too small for its Elements, when it was hot.

Not to be attenuated by Fire.

This then being constantly observed to be the case, we conclude, that Fire, let its force be applied and continued in what manner you will, can never divide the Elements of Water into smaller Particles, but can only with its utmost effort extend them into a larger Bulk, and then strongly agitate them among one another; which seems to be the limits of the efficacy of Fire upon Water. Rain-water, which was caught upon the Observatory of our Academy, I distilled in very clean Vessels, and with a gentle Fire, and after having kept it some Years well stopped, I found it exactly the same, without the least difference, whether chemically examined, or hydrostatically.

But always kept in motion by it.

Since 33 degrees of Heat now dissolves Water in such a manner, as to render it fluid, hence we are certain, that the particles of Water are always in motion, so long as by this Heat it continues to be Water: For this Heat, in which Water is turned into Ice, is more than $\frac{1}{3}$ of the greatest natural Heat; and certainly a Fire so great as is able to melt hard Ice, must necessarily be capable afterwards of keeping its Particles in motion. Hence, therefore, we suppose, that Water, though considered together as at rest, has its Particles kept in a constant agitation. Nay, and the solution of Salts, too, in Water, seems to evince, that its Elements are in continual motion; though this solution, indeed, appears rather to be attributed to attraction, than repulsion: In the mean time, however, it don't seem likely that the whole Mass would be dissolved, unless the agitated Elements of the Water were kept constantly moving from one place to another, and by this means were successively applied to the solvent Salt. By the help of Microscopes, likewise, we are able to perceive a motion in the Particles of Water. And lastly, it is plain, Water must be rarely at rest, in any Vessel whatever, as every thing almost on which it can stand, is continually affected with a tremulous motion.

And immutable.

Hence, therefore, are not the ultimate Elements of Water perfectly immutable? Certainly they seem so firm and constant to the Figure, which once they are formed with, that no power of Art or Nature has yet appeared capable of altering it. And this will always hold equally true, whether you consider them singly and separately, or as they are collected together, and compose one Body. For since from every Operation it returns constantly the same as when it was applied, neither becoming denser or rarer, heavier or lighter, thicker or thinner, it plainly demonstrates, that both the bulk and figure of its Particles have remained the same: For if by the force that acted upon them, their figure had been changed, then the contact of the Elements had been changed likewise, and consequently, there must have been some alteration produced in the Interstices between these Elements, whence would arise some difference in the density and gravity of the whole Body. Suppose, for instance, the Elements

ments of a Body to be spherical, and that these afterwards, by being compressed together, are changed into Cubes, then the Interstices between the spherical Elements, in the first case, being the greatest possible, would produce the greatest lightness, and rarity, which being quite filled up by the Cubes, in the last, the Body would acquire its greatest density and gravity: But nothing of this nature is ever observed in Water. In the *Æolipile* exposed to a very strong Fire, the Water, by the violence of the Heat, the resistance of the Vessel, and the straitness of the passage through which it is let out, is prodigiously agitated, divided, and rarified; and yet the Vapour received into a Vessel gives you always the very same Water that was put into it.

These Elements, therefore, ought by no means to be looked upon as a kind of little flexible Eels, moving about in sinuous convolutions, as the subtil *Descartes*, and the famous *Stairs*, have imagined: But on the contrary, the ultimate Particles of Water seem to be exceeding rigid, perfectly inflexible, and of an adamantine hardness. Are they therefore perfectly solid Spheres? This seems sufficiently probable. If the Air, therefore, that is intercepted betwixt these Elements should reside there in a spherical form too, then the Space taken up by the Water, would be to that taken up by the Air, as 100 to 7, nearly as 14 to 1, according to the computation of the ingenious *Cruquius*. Nor flexible.

But again, by various, and unexceptionable Experiments of the Academy *del Cimento*, it has been made evident, that the Elements of Water are not compressible by any force whatever. p. 197 to 207. *Du Hamel* likewise informs us, that a Sphere of Gold, when it was perfectly filled with Water, could not be compressed. That a Leaden Sphere, indeed, full of Water was compressible by the Hammer, *Colbertus* tells us, *Physic. General.* Part I. p. 4. Lord *Verulam* relates too, that a Tin Sphere, being filled with Water, and then strongly compressed, upon making a hole in it, made the Water fly out. *Boyle* asserts, that it threw it to the distance of three feet. Exper. 20. and *Stairs* affirms the same, p. 396. These last Experiments therefore seem to invalidate the Opinion of the Academy abovementioned: But here there are two things that ought to be carefully considered. In the first place, in the filling of these Vessels, the Air may easily insinuate itself, and lie concealed betwixt the Sides of the Vessel and the Surface of the contained Liquor; and if this is the Case, then when it afterwards comes to be compressed, it will press out the Water wherever there is a vent, till it is reduced to the common density of the Atmosphere. And secondly, as I hinted before, the Particles of the Metal being distended upon the Water, and endeavouring to contract themselves, must, upon any Hole being made in the Vessel, immediately force out the Water. These instances, therefore, are not sufficient to prove any compressibility, or elastic Spring, in the Water, which the *Florentine* Experiments seem intirely to destroy. Hence, then, Water, in respect to compression, and the density that arises from it, appears to suffer nothing at all from the different weight of the Atmosphere, let the variation be ever so great. And here certainly the Works of the Author of Nature appear very wonderful, whilst we see one Element, as Air, formed with almost an infinite Elasticity, whilst another, as Water, is not elastic at all. In making all these Experiments, however, what a prodigious deal of caution is necessary? For if there is but the Nor compressible.

least common Air, besides what is in the Water itself, intercepted and detained between the concave Surface of the Vessel and the convex one of the Water, which may easily be the case, as we see by the Bubbles formed upon the polish'd Surfaces of smooth Bodies immersed in Water; I say, if there are any such Bubbles as these, though they are first exceeding small, yet afterwards, by being united together, they may form there a considerable quantity of Air, which, upon being compressed, will exert a very great expansive force, which one may be easily led to ascribe to the Water itself. But we must be very careful, likewise, that, during the time that the Experiments are making, the Heat of the Water is neither increased nor diminished; for as the expansion of Water upon Heat, and its contraction upon Cold, is very considerable, by this means, likewise, the event may prove fallacious. But in the third place, we may here take notice farther, that though the Air which is lodged in the interstices left between the Elements of Water, has there no actual elasticity, yet, when it is expanded by a certain degree of Heat, is forced out thence by a hydrostatical force, and becomes united together, it then acquires an elastic power, in the same manner as it does in the Air-pump, when it is absolutely drawn out of it; if this then should happen to prove the case here, the Air which before being dispersed through the Water, did not appear elastic, now it is separated, and not immediately absorb'd again into the Water out of which it was express'd, will exert a true elastic force. Except therefore all these cautions are carefully attended to at once, an error may easily happen in these Experiments: For which reason it always ought nicely to be examined, whether there are any such Bubbles in these Vessels, or no.

Water exceeding simple.

The fourth property which the order of our Subject leads us to take notice of in Water, is its exceeding great simplicity: For if it is pure elementary Water, it does not discover the least diversity in its parts, so that it is every where found to be exactly the same; and by what has been already laid down, it appears to be immutable in its bulk, figure, density, weight, and other Properties. The Alchemists now observing this constant simplicity of Water, fell into an opinion, that all Bodies, in particular the more simple ones, were produced from Water alone, as their original Matter, by means of a seminal faculty in their Seed, and a quickening Fire. Hence *Paracelsus Archid.* x. c. 3. Water is the proper Element or Sea, that is, the true Mother of all Metals. And *Helmont* throughout his whole Works endeavours to advance and inculcate this Doctrine. And for this reason they asserted farther, that all Bodies, when they are perfectly and radically dissolved, by the universal Solvent, are at last reduced into a homogeneous, elementary Water, their particular, seminal power being quite destroyed. Consult *Helmont* in every part of his Writings. This Opinion, however, seems rather founded upon History and Disputation, than any Experiments which have been related in such a manner, that a sober man can fairly give credit to them. For after *Moses*, the most ancient Writer, had delivered a tradition, that the Spirit of God, brooding upon the face of the Waters, had communicated to them a prolific virtue, the wisest of the ancient *Persians* looked upon Water as the principle of Bodies. Hence the same doctrine came to be in vogue among the *Egyptians*, from whom *Thales* the *Milesian* carried it into *Greece*, by which means it at last came amongst the Chemists. Hence the followers of *Van Helmont* acknowledged only

only two simple, natural Bodies. viz. Water perfectly separated from every thing foreign, and heterogeneous, and Mercury freed too from every thing heterogeneous, and from the taint of its own inherent, original Sulphur, whose simplicity then would be greater than even that of Gold. Mercury, however, itself they asserted to be the offspring of Water, from which it originally has its rise, and into which it may at last be resolved. Hence they supposed Water to be the universal nutriment by which all Bodies are supported, which no Art whatever is capable of making any alteration in, but only the innate faculty of created Seeds.

As a fifth property of Water, we reckon its mildness. And this quality it is endued with to such a degree, that if it is reduced to the Heat of a healthy Body, and then applied to any of its parts, which have the quickest Sense, it not only don't excite any pain, but it don't so much as raise any other sensation than what is caused by the natural humours, and the parts feel when they are perfectly sound. If, for instance, it is applied to the *Cornea* of the Eye, than which there is scarce any part sooner affected with pain from any thing sharp, it does not cause the least uneasiness. To the Membrane of the Nose, which is made up of Nerves that lie almost bare, it is neither troublesome, nor affects it with any new smell; nay, if you apply it softly to the Nerves, when they are stretched with an inflammation, and from any very light cause grow so exceeding painful, it produces no manner of inconvenience. In crude Ulcers, which can't bear the least touch of the softest thing without uneasiness, warm Water causes no irritation at all: Nay, foment even the bare and half-destroyed Nerves of an ulcerated Cancer with warm Water, and instead of increasing the sharpness of the Pain, you will assuage it; whereas if you apply any thing else to them, it will make it worse. The organs of smelling it does not affect with any smell, those of tasting with any taste, those of seeing with any colour, or the nerves with any sensation. Among all the humours of the human Body, it is found to be the mildest, even the Oil itself not excepted, which, let it be ever so soft, by its tenacity gives the Nerves a kind of uneasiness. And among those Elements which Art is capable of extracting from these humours, Water, when it is pure, is always observed to be the most mild. And lastly, it demonstrates its excellent mildness, by being able to dilute things acrid, in such a manner as to deprive them of their natural acrimony, and render them harmless, with respect to the human Body. A drachm of the Liquor drawn from Vitriol, for example, by the extreme force of Fire, called by the Artists the purest Oil of Vitriol, drank by a person with an empty stomach, would prove a violent poison, burning up his throat, *œsophagus*, and stomach; and yet if the same is diluted in six pints of Water, it will do no harm, though you drink it all. And in other instances the same thing nearly holds true.

Exceeding mild.

In respect, therefore, of both these qualities, warm Water is esteemed one of the principal Anodynes, and Purgatives in Physic, and is hence recommended by *Hippocrates* as the softest Fomentation for the sharpest Pains.

Hence an Anodyne.

The sixth property which we observe in Water, is its dissolving power, by which it is able to dissolve certain Bodies in such a manner, that when they are diluted in it, you will have a Fluid, in which the dissolved Bodies shall be so equably distributed, that in every part of the Water there shall be a

The dissolving power of Water.

proportional part of the solvend. As this speculation, now, is of considerable consequence, so it will be most readily understood, by examining in order those Bodies upon which Water is capable of acting in the manner described; and these are as follows.

First upon
simple Salts.

First, all true, simple, fossil Salts, whether existing in a liquid or solid form. Hence *Sal-Gem*, Fountain Salt, Sea Salt, Borax, Nitre, *Sal-Ammoniac*, and the alkaline Salt of Chalybeat Waters, as it is justly accounted by the famous *Hoffman*: As likewise the fossil, acid Salts, which are rarely found in a solid form, but being almost always liquid, are referred to the Acid of Sulphur, called the Oil or Spirit of Sulphur *per Campanam*; to the Acid of Alum forced out by an extreme Fire, called Oil of Alum; to a similar Liquor, drawn in the same manner, from Vitriol, called Spirit or Oil of Vitriol; all which three sorts of Acids, being perfectly depurated, and reduced to their greatest simplicity, seem hardly at all to differ from one another. It is exceeding difficult indeed to free them intirely from all their Water, and when you have done it, they immediately attract more into them out of the Air, as greedily as fixed, alkaline Salts do, when they are dried in the strongest Fire. When you have separated it from them, however, very nicely, they may be kept some time in the Cold, in form of solid Chrystals; but as soon as ever they attract any moisture out of the Air, they melt again, or if they are exposed to a somewhat greater degree of Heat, for then, like Ice, they perfectly become fluid. Hence, however, we see, that these acid Salts, when they are quite freed from their Water, are capable of acquiring a solid form, though they retain it with a great deal of difficulty. The other simple, fossil, acid Salts, are the acid Spirits of Nitre and Sea Salt; and these are always fluid; for they are of so volatile a nature, that they themselves fly off with that degree of Heat, that is necessary to separate their Water. All these fossil Salts, now, may be dissolved in Water, according to the Law abovementioned.

In a different
manner.

In the solution, however, effected in this manner, there is observed a very considerable and manifold diversity. For in the first place acid Salts, that are almost always liquid, and therefore are already diluted with such a quantity of Water, as to render them fluid in a certain degree of Heat, may be dissolved in any quantity of Water whatever, be it ever so small: If you take, for instance, a pound of the strongest Oil of Vitriol, and mix it with only one drachm of Water, you will so accurately divide the Elements of the Oil of Vitriol, that it shall be all perfectly dissolved in this one drachm of Water. And this is the case of all other acid Salts, that we are hitherto acquainted with. But on the contrary, those fossil Salts that are of a solid form, will not suffer themselves to be dissolved, except you apply to them a certain quantity of Water. If you make use of less than is necessary for this solution, then, such a part only of the Salt will be melted, as that quantity of Water will take up, the remainder still continuing solid. When these Salts, however, are once perfectly dissolved in a proper quantity of Water, they may afterwards be farther diluted in any quantity whatever. Take, for instance, an ounce of dry *Sal Gem*, and dissolve it in three ounces of Water, and you will have a simple *Lixivium*, to which, if you add only one scruple of Water, the *Lixivium* will be perfectly and equably diluted by it. And this property, certainly is very remarkable, inasmuch as there is no end to this dilution; for when a fossil Salt is once dissolved

dissolved in Water, it may afterwards be diluted in the smallest or greatest quantity of Water, in such a manner, that in every portion of the solvent Water there shall be a proportional part of the dissolved Salt. But in this dissolving power of Water it is observed, in the second place, that if the Water poured upon the Salt is shook about with it, the solution is sooner effected, and more Salt is dissolved; whereas, if it stands quiet, it is longer about, and the Water takes up less. In the third place, hot Water dissolves Salt in a great deal less time than Cold, and takes up, and retains a great deal more. Hence Water that has only 32 degrees of heat in it, performs its office slowest, and dissolves least Salt of all; whilst boiling Water, which has 212, does it quickest, and dissolves most. And this is always observed to happen in proportion to the degree of Heat and Cold. For if you dissolve Salt in boiling Water, 'till the Water is perfectly saturated, and then remove the Vessel from the Fire, you will observe, as the Water grows gradually colder and colder, it will continually precipitate more and more Salt to the bottom, 'till at last, when it is reduced to the 32d degree of Heat, it will have discharged a very large quantity of Salt in a solid form; and if then by a still greater degree of Cold, this salt Water begins to freeze, there will in that case be yet more Salt separated from it, so that in the sharpest Cold of all it will be nearly all expelled, and so long as that Cold continues, will remain with the Ice, of a solid consistence. But again, the salt Water, which when acted upon by so sharp a degree of Cold, discharg'd the greatest part of its Salt, will be much sooner thaw'd again upon the application of Salt to it, than common Water will without, in the same degree of Cold: For as Salt, on the one hand, by being mixed with Water, keeps it from freezing, 'till the Cold is increased a good deal below that point in which pure Water would have froze: So, on the other, if you apply Salt to Ice in that very same degree, precisely, in which if the Salt had been mixed with the Water, it would have been just upon freezing, it will reduce this Ice to Water, though without it, the Ice would have required several more degrees of Heat to dissolve it. By this surprizing property, then, we see, that Salts have a power to prevent the association of the parts of Water, and their concretion into Ice, and that by the application and interposition of their own Particles. Hence the Water of the Sea is a good while longer before it freezes than fresh Water, and requires a much greater degree of Cold. In the fourth place, the concretion of Salt, before dissolved in Water, called chrySTALLIZATION, appears from what has been said to arise, first, from the want of a sufficient quantity of Water to dilute it; secondly, from the Liquor's being at rest, in which the Salt is dissolved; and, thirdly, from Cold: For these three are the instruments by which chrySTALLIZATION is brought about. But in the fifth place, we observe farther, that the dissolving power of Water operates much sooner upon one Salt than another; as we see *Sal Gem* is sooner dissolved, in the same Water, than Borax: and the same quantity of Water too will dissolve more of one Salt than another, as we see likewise in the same Salts. And sixthly and lastly, when Water is so perfectly saturated with one kind of Salt, that if you add any more it will fall undissolved to the bottom; yet even then it will be capable of dissolving a good deal of another sort, and that without letting go the former. Saturate, for instance, Water of a certain degree of Heat with *Sal Gem*, so that it won't dissolve the least grain more, and it will, nevertheless, take up a small quantity.

quantity of Nitre; and yet the *Sal Gem* will remain perfectly dissolved in the Water as before. Nay, and when it is thus saturated with these two Salts, it will still be able to dissolve somewhat more of another. If the Philosophers and Chemists, therefore, would properly consider these *Phænomena*, it would open a way to farther inquiries into the nature of the Solution that Water exerts upon Salts, than have yet been made.

Secondly,
upon com-
pound Salts.

In the second place, pure Water dissolves those Salts that are called Metalline, or Terrestrial Salts; by which we mean the Chrystals or Vitriols produced from Metals corroded by Acids; and that, whether these Acids are Fossil ones, as in Vitriol and Alum; or Vegetable ones, as in Verdigrease. All these Vitriols, now, it appears by chemical Experiments, are compounded of a solvent Acid, a Water diluting this Acid, and a corroded Metal, united by a certain Law, and in a certain proportion into one Glebe. Whilst all these Bodies are thus dissolved in Water, the same six conditions just now mentioned, will hold good in these likewise.

And upon
those of A-
nimals and
Vegetables.

But in the third and last place, Water has a power also of dissolving the Salts, both of Animals and Vegetables, whether native, or produced by Art. Acid, Rough, Salt, Alcaline, Compound, Ammoniacal, Fix'd, Volatile, Semi-fix'd, and Simple ones, those arising from a Salt and Oil, combined together, and those produced by Fermentation, Putrefaction, and Combustion, are all dissoluble to Water. But here again, there is observed the same variety in the solution, as we observed above. And among all these different kinds of Salt, Tartar is dissolved with the greatest difficulty.

These things
confirmed by
Experi-
ments.

All these things, now, I'll demonstrate to you by various Experiments. First, then, in this Glass, I have an ounce of pure Water, into which I drop four drops of Oil of Vitriol, and upon shaking it together, the Liquor through the whole grows equally acid. 2. Here again, I have an ounce of Oil of Vitriol, into which I drop four drops of Water, and upon shaking the Vessel, the Liquor, as before, becomes uniformly acid. Hence then it appears, that acid Salts, whether mixed with Water in a greater or less quantity, are most equally divided by it, and most intimately dispersed through it. 3. With an ounce of Water, I mix half an ounce of dry Sea-Salt, part of which dissolves, and the remainder lies undissolved at the bottom. 4. To a very strong Brine of Sea-Salt, I add any quantity of Water whatever, and they very equably mix with one another. 5. If the same is performed with Nitre, *Sal Gem*, Borax, *Sal-Ammoniac*, Salt of Tartar, a dry alkaline Salt, a volatile alkaline *Sal-Ammoniac*, with Alum, or Vitriol, the effect will be perfectly the same, as in the third and fourth Experiments: All which I have here set before you. These Salts, therefore, in order to be perfectly dissolved, require always a certain determined quantity of Water, nor can Water dissolve solid Salts, but to a limited portion of them. All these Salts, now, that I here made use of, were first very carefully dried, and reduced to a very fine Powder. If we could, by any Art now, perfectly free acid Salts from all the Water that is mixed with them, it is very probable, that their Particles being then united and concreted into a solid form, would in a certain degree of Heat require a determined quantity of Water to reduce them again to a state of fluidity: For if the strongest Oil of Vitriol is exposed to a great degree of Cold, it requires a certain portion of Water to prevent its shooting into solid Chrystals; nor will that which is diluted

diluted with Water thus congeal in the Winter, but only that which is exceeding pure. It is not an easy matter, however, to give you an instance of exhibiting pure acid Salts in a solid form, without the concurring assistance of a very great degree of Cold; and hence Persons have generally imagined, that these acid Salts may be always diluted with the least quantity of Water; but this, you see, must be understood with some restriction, agreeable to what we have now observed. And thus much for the proof of the first propositions.

Into three ounces of the purest distill'd Water, I here put one ounce and one drachm of Sea-Salt, all which, if they stand at rest, will dissolve in time, tho' slowly; but if they are shook strongly together, it is all dissolved presently. To the same quantity of Water, in each of these Vessels, I add the same quantity of Salt, but one of them I keep here in the Cold, whilst I set the other upon the Fire; and the Salt in the warm Water dissolves much sooner than that in the Cold. With twelve ounces of distill'd Water, I here mix five ounces of Sea-Salt, and upon boiling them together, they are intirely dissolved: I add now as much boiling Water as was lost by boiling, and you see in this degree of Heat, there is a perfect Solution. I cover the Vessel that nothing may exhale, and set it by to cool, and the Salt concretes again in the Cold, and from the degree of ebullition, quite down to the degree 32, this *Lixivium* of Sea-Salt, which was as well saturated as it could be rendered by boiling, forms and deposits every moment more and more Salt. Hence then we learn, that the same quantity of Water in the Summer time, takes up more Salt than it does in the Winter; in a hotter Climate dissolves more than it does in a cold; and consequently, most of all in the Torrid Zone, and least about the Poles: But as putrefaction, *ceteris paribus*, prevails in proportion to the degree of Heat to which Bodies are exposed, we see it is wisely provided, that in hot Countries there should be so much more Salt dissolved than in cold ones, which best resists it. Boiling Water, then, will dissolve as much Salt, as Water can possibly take up: Water that is in the very next degree to freezing, least of all. But even Ice itself congealed from Salt-water in every increasing degree of Cold down to 0 in *Fahrenheit's* Thermometer, discharges continually more and more Salt, so as at last to retain but an exceeding small quantity, in the greatest observed natural Cold. All these Observations, then, make it evident, that in the Elements of Water there is a natural disposition, which, when they are acted upon by Fire, makes them liable to be so separated from one another, that the Particles of Salt may be disposed in the Interstices between them: And that on the other hand, when the Heat is withdrawn, and they are left to themselves, they then spontaneously attract one another in such a manner, as to lessen these intercepted spaces, so that the Particles of Salt can remain there no longer, but upon the nearer approach of the aqueous Elements are expelled from between them. The dissolving power of Water, therefore, with regard to Salt, depends partly upon the Salt and Water, and partly upon the quantity of Fire that is united with them both. And hence, tho' most of the Chemists, indeed, would have it otherwise, it is evident, that it is impossible to determine how much Salt may be dissolved in a given quantity of Water, unless the degree of Heat is first accurately adjusted in which the Solution is performed. And for this reason, it seems certain, farther, that Water, without the assistance of any Heat at all, is not able to dissolve the very least quantity of Salt, that is, that Salt will not be

The quantity of Water necessary to dilute Salts.

be diluted by the very coldest Ice. And here, again, it is very remarkable, that Salt, by being mixed with rasped Ice should make it thaw, and yet by the very same means should excite such a prodigious degree of Cold: This appears every where evident, but most of all so in those Experiments of *Fahrenheit's*, which we related to you, p. 99, which certainly evince, that Salt has a power of heating the coldest Bodies, and of expelling Cold from them into the neighbouring Bodies and Spaces; which again, is a wonderful Law of Nature. But as I am not treating professedly of this subject now, I must proceed, tho' I have a good many more things that I could add, which, perhaps, I may do hereafter: What I have offered, will in the mean time afford you matter of speculation and farther inquiry. Give me leave, however, to propose a few more Experiments which I have made relating to our present business. When the common Air was 38 degrees warm, I took of the purest driest Sea-Salt reduced to a fine powder 2 ounces, which suffered themselves to be dissolv'd in 6 ounces 3 drachms of pure distill'd Rain-water; so that here 4 parts of Salt required 13 parts of Water. One ounce of *Sal Gem*, prepar'd in the same manner, required 3 ounces 2 drachms of the same Water, the proportion here being the same as the former, viz. 4 to 13. One ounce of pure dry powdered *Sal-Ammoniac*, was dissolved in 3 ounces 2 drachms of the same Water. Nine drachms of pure dry Nitre, reduced to Powder, took up 6 ounces of the same distill'd Water; so that there were 3 parts of Nitre, to 16 of Water. Half an Ounce of very dry Borax, required more than 10 ounces of Water to dissolve it intirely; hence the proportion, as 1 to 20. One ounce of Alum was dissolved in 14 ounces of distill'd Water. One ounce of *Epsom* Salt, in 1 ounce 2 drachms: One ounce of Salt of Tartar, in 1 ounce and $\frac{1}{2}$. Three ounces of Water, shook strongly, and for a good while, with $\frac{1}{2}$ an ounce of the *Arcanum Duplicatum* of the Duke of *Holface*, dissolved it perfectly. And lastly, by shaking them together for some time, 3 ounces of Water dissolved intirely 1 drachm and $\frac{1}{2}$ of common green Vitriol. Hence, then, we infer, that different Salts require a very different quantity of Water to dissolve them: That some are dissolved sooner than others: That those which spontaneously melt in the Air, dissolve soonest, and in a very small quantity of Water; which too seem of a more active nature: And that these, when they are exposed to the Fire, part with the Water in which they are dissolved, with so much the more difficulty, so that Salt of Tartar, and Oil of Vitriol, cannot be freed from their Water without a very great degree of Heat. To these 3 ounces 2 drachms of Water, now, which has dissolved in it 1 ounce of Sea-Salt, nor is capable of taking up any more of this Salt, I add $\frac{1}{2}$ a drachm of Nitre, and this dissolves in it. Again, with these $6\frac{1}{3}$ ounces of Water, which contain 1 ounce of dissolved Nitre, and are perfectly saturated, I mix $\frac{1}{2}$ an ounce of Sea-Salt, and it dissolves intirely. Hence, therefore, Water, when it is saturated with one sort of Salt, so that it cannot take up any more of that, is nevertheless still capable of dissolving some more of another. Fountain-Salt, *Sal Gem*, Sea-Salt, *Sal-Ammoniac*, Nitre, and Borax, being reduced to their particular Brine, may be intirely and intimately mix'd with one another. In the Solution, however, of a metallic Vitriol by Water, it ought particularly to be taken notice of, that this cannot be perfectly dried before this Solution, but it will be altered in its Nature: Nay, and whilst it is dissolved in this manner, it always lets fall to the bottom a good deal of

of indissoluble Ochre; and hence by repeated Solution and Chryftallization of Vitriol in Water, the whole substance is at last converted into Ochre, and a pinguious Liquid, that cannot be easily dried. The easier, therefore, the sooner, and with the less quantity of Water, Salts are dissolv'd, the more strongly they seem to retain their Water when they have once received it. But in the Solution of Metals, now, by Water, there are some *Phænomena* that are very singular, and well worth our consideration. Metals have some Salts, by which they may be dissolved; and when they are found dissolved by these into vitriolic Glebes, they then suffer themselves to be diluted in Water: And this Solution is always soonest effected, and is most perfect, when these Glebes abound with that Salt, which such a particular Metal is principally dissolved by; for then pure Water will so perfectly dilute such a Glebe, that the metallic Particles will be most equably distributed through the Water. But on the other hand, when in Vitriols, part of the solvent Salt is wanting, then Water poured upon them, will dissolve the Metal so much the less, so much slower, and more imperfectly, especially if you add too great a quantity; for then there is always some part of the Metal precipitated to the bottom. But when Metals are dissolved in a good quantity of their solvent Salts, and then diluted with Water, by a gentle exhalation they are reduced into solid vitriolic Glebes called Magesteries, Salts, Vitriols, Sugars, and Chrystals of Metals. In all these now, the Metal, its solvent, and pure Water, are always combined together in a certain proportion, and form pellucid, brittle Masses, dissoluble in Water, fusible in the Fire, and hence convertible into a fine Calx, which lose their transparency, as soon as ever the Water is drawn from them. By this Art, now, Metals are rendered potable, without much inconvenience, and with a medicinal effect that may be pretty certainly determined, as they are thus rendered dissoluble in Water. For in the first place, these Bodies will act by the Acid which dissolves the Metals, and then adheres to them. Secondly, by virtue of the metalline Mass dissolved by this Acid, and now in the Vitriol; for this metalline part will then act by the properties common to all Metals. And thirdly, in which their principal efficacy consists, these Vitriols will act by that singular virtue which is proper and peculiar to every particular Metal, and which is generally inimitable by any other. But fourthly, these Bodies likewise acquire a farther power, arising from the union of these three together, thus all united by the mediation of Water, in particular, into one Mass, which now acts by their whole joint efficacy. Of this kind now, thus produced by Water, are Vitriols of Gold, Mercury, Lead, Silver, Copper, Iron, and Tin.

This rule, however, must not be extended to all Semi-metals, as if Semi-metalline Particles, reduced by their solvent Acids into Masses appearing saline, might be afterwards diluted, and dissolved in Water like Salts, and true Metals. The purest metalline part of *Regulus* of Antimony, for instance, is perfectly dissolved in the strong Spirit of Sea-Salt that adheres to the corrosive sublimate of Mercury, in the distillation of Butter of Antimony; for what else is this Butter of Antimony, but a true vitriolic Salt of *Regulus* of Antimony, made by a combination of it with Spirit of Sea-Salt? Hence, therefore, from our History of metalline Salts, a Person would be apt to imagine, that this Butter, likewise, might be dissolved in Water; but how much would he be disappointed, when he came to make the Experiment? For as soon as ever the Water

Water don't
dissolve all
metalline
Salts.

X x

comes

comes to this icy Glebe, the solvent Acid immediately lets go the dissolved *Regulus*, mixes itself with the Water, and gives you again intirely the semi-metalline corroded *Calx* that lay conceal'd in the Butter. This rule, therefore, must not be carried beyond its proper limits.

Water dissolves Alcohol.

Water dissolves Alcohol, not spontaneously, but if they are shaken together; for if Water is gently poured upon Alcohol, it passes through it, and falls to the bottom, whilst the Alcohol swims at top. Nay, it will not readily so dissolve Alcohol, but that after you have shaken them, the Alcohol will still in some measure cohere together, and float about in the Water in pinguious *striae*: If the concussion, however, is continued for a good while, it will at last be perfectly diluted, and equably distributed through the whole Water. This tenacity, now, of the parts of the purest Alcohol, appears no where more elegantly than in an Experiment I formerly shewed you, p. 258, when I took a chemical Vial full of Water, and inverting it, immersed the mouth into Alcohol, for then you saw the Alcohol ascend through the Water without mixing with it, rise into the Belly of the Glass, and collect itself together at top. Since, therefore, pure Alcohol is a vegetable Oil reduced by the efficacy of a proper fermentation into these Spirits, which burn, and are miscible with Water;

Therefore fermented Oils.

Hence we learn, that even Oils themselves, after they have first been chang'd in this manner, may be intirely mixed with Water, let them be ever so pure, tho' sooner, indeed, and more easily, if they are diluted in some quantity of it already; for common Spirit of Wine mixes more readily with Water, than the purest Alcohol.

Water and Salt don't dissolve Alcohol.

In the mean time, however, it is particularly remarkable, that Water, when it is perfectly saturated with Salt, will by no means mix with Alcohol; nay, if you shake them together ever so strongly, and for ever so long a time, you will never reduce them to one uniform Fluid, but will find on the contrary, that they repel one another much more powerfully than any other two known Liquors in Nature. In this Vessel here, I have some Oil of Tartar *per deliquium*, in this other some Alcohol, both of them pure transparent Liquors: These, now, I mix together, and you see they continue perfectly distinct, the Oil of Tartar subsiding to the bottom, whilst all the Alcohol swims at top. But I'll shake these now with all the force I am able, and what is the consequence? Why the Oil again collects itself together, and the Alcohol rises united above it, nor so much as the least drop of either of them remains mixed with the other. Nay, farther, I put these two Liquors into a tall Bolthead, and made them boil, in order to try whether by this means I could not make them mix together, but I found it was to no purpose, for both of them continued perfectly separate from the beginning to the end, even in the act of ebullition, but the Alcohol being raised by the strength of the Fire, was separated from the Water, which remained at the bottom with its Salt.

Water sometimes attracts Alcohol, and deposits Salt.

But there is still something farther very extraordinary in this affair, and that is, that if Water is thoroughly saturated with a Salt that may be very easily separated from it, then if you mix the purest Alcohol with this *Lixivium*, the Alcohol will unite with the Water, and the Salt will be expelled and precipitated to the bottom in form of a dissolved Salt. In this Glass I have the strongest *Lixivium* that can be made with *Epsom* Salt and Water, which you see is quite

quite clear, nor has the least sign of any Salt in it. Into this, now, I pour some Alcohol, and it swims at top: But I shake them as you see together, and now the Liquor grows turbid, opake, and whitish, and lets fall some little Chrystals of Salt, by this means separated from its dissolvent Water, which is now united with the Alcohol. And in the *Offa Helmontiana*, where there is as much volatile alkaline Salt of *Sal-Ammoniac*, dissolved in Water, as it can possibly take up, and then an equal quantity of the purest cold Alcohol is poured upon it, the Liquors being shaken together, instantly coalesce into a white solid Glebe, from which in a little time there is separated some Water attracted into the Alcohol.

But another thing to be observed in this dissolving power of Water is this, that if it is mixed with Alcohol, that has a distilled Oil dissolved in it, then the Oil will be separated from the Alcohol. This you'll see, if you'll please to attend to the following Experiment. I have here some exceeding pure Alcohol, in which I have dissolved some choice Oil of Cinnamon, and you perceive how equably clear it is, without the least sign of any Oil swimming in it, or falling to the bottom. Into this mixture, I now gently drop some Water; and don't you observe how the Liquor immediately grows white, and from a transparent one, becomes opake? But you observe farther too, that the Oil, which before was so perfectly diluted, as to become imperceptible, discovers itself now, and collects itself together. Hence, then, it appears evident, that Water, being mixed with Alcohol, renders it unfit for the Solution of these Oils: That Alcohol unites more easily, and in a more kindly manner with Water than with these: And that these Oils, when they are diluted with Alcohol, do nevertheless continue real Oils, tho' they do not, during that time, appear in form of Oil, but of Spirits. Refins too, may be dissolved in Alcohol, so as not in the least to appear; but if you mix Water with this Liquor, it instantly becomes very white, discovers again the latent Refin in the Alcohol, and yields you the very same quantity of Refin that was dissolved: This is true in every kind of Refin whatsoever. These resinous Substances, therefore, may be dissolved in Alcohol, may be recovered from it again by the help of Water, may be dissolved again, and precipitated as before, and this may be repeated as long as you please. This I learned by a great number of repetitions of these Operations in Refin of Scammony. But let us take Camphire a little into consideration: What kind of Body do you look upon this to be? You'll be apt to answer, a Refin. Shew me then any other Refin in the World, that may be sublimed dry, without any *residuum*, or any alteration in its parts: In this particular, therefore, it is different from all Refins: This, however, may be perfectly dissolved in Alcohol, and upon the affusion of Water, exactly like other Refins, will be recovered into true solid Camphire, intirely the same as it was before. Upon the whole, then, it appears, that Water attracts Salt of Tartar more powerfully than it does Alcohol: Whilst on the other hand, it attracts Alcohol more strongly than that does Oils, Refins, and Camphire.

Water dissolves the Alcohol out of Oils, Refins, and Camphire.

But Water, again, dissolves every composition that is properly called a Soap, or a saponaceous Body, and that, whether it is artificial, or natural: Nor does it at all signify, whether it is fixed or volatile. For every *Sapo* is compounded of an Oil and an alkaline Salt, so united together, that they may be diluted in Water in such a manner, that there shan't be the least appearance, either of

It dissolves Sapo's, and saponaceous Substances, and by this its Power is increased,

the Oil or the Salt, but the whole mixture shall appear homogeneous. The particular property now of such a Substance is this, that if it is intimately mixed with Oils, oily Substances, Refins, resinous Substances, Gums, and gummy Substances, Gum-Refins, or any other tenacious Bodies formed from these, it will render them miscible, and dissoluble in Water, so that they may by this means be washed off from the Bodies to which they adhere. Water, therefore, not only dissolves true Soaps, but by being assisted by them, acquires a power of dissolving those Bodies, which otherwise would have been beyond its efficacy: The dissolving Power, therefore, of Water, by the help of Soap is vastly increased.

Water dissolves Air.

One would scarcely have believed, however, that Water had a power of dissolving Air, unless this had been absolutely demonstrated before in our History of Air. See p. 299, 300. But this in the mean time is effected only in a particular manner, and to a certain degree, but no farther; and indeed, with this circumstance, that the Air, whilst it continues thus dissolved, no longer retains that elastic quality which is proper to it. See the places just cited. In this respect, therefore, Water dissolves Air, as it does Salts, that is to say, in such a manner, that the small Particles of Air dispose themselves between the interstices left between the Elements of Water, as those of the Salts do; and whenever all this Air is perfectly separated from its dissolvent Water, by Frost, the removing the pressure of the Atmosphere, Fire, the Sun, or the Mixture of certain Bodies together, there is then immediately just so much Air imbibed by the Water as was disengaged from it.

And earthy Bodies, first prepared.

In the last place, Water is capable of dissolving many earthy Bodies, when they are first prepared; tho' whilst they were alone, they could never be diluted, and dissolved by it. Oyfter-shells, the Claws, and other shelly parts of Lobsters, and Cray-fish, the Shells of Snails, and River and Sea-fish, Stones, the *Calculi*, and stoney concretions in Animals, their Horns, Hoofs, Bones, and the like, when they are first perfectly corroded by their proper solvent Acids, may be afterwards intirely dissolved in Water: Nay, and Chalk, Corals, Pearls, Mother of Pearl, calcined Stones and Flints too, have long been instances of the same thing.

Other Bodies it cannot dissolve.

Having thus then given an account of the Bodies that Water is capable of dissolving, it may be properly enough inquired, which then are those that are capable of standing out against this dissolving power? Why, to this question we shall then only be able to answer, when we are certain that we are masters of some Water that is absolutely pure, without the least Mixture of Salt; for Bodies are very often dissolved by the vertue of latent Salts, and the effect is falsely ascribed to the Water itself; whereas, was this Water quite pure, we might then be able to judge, whether this vertue belonged to the Water alone. In Metals, in particular, the thing is exceeding difficult, inasmuch as Iron, when wetted with the purest Rain-water, is converted into a Rust, and Copper into a Mould. The famous *Joel Langelotte*, indeed, has in his Writings asserted, that Gold may be dissolved by attrition alone: And the ingenious *Homborg* affirms, that simple Water, by being rubbed for a long time with Metals, nay, even Gold itself, is capable of perfectly dissolving their Substance into a potable, medicinal form. These Experiments I have read and examined; but as these have been made in the Laboratories of Chemists, where the Air is impregnated

nated with all kinds of volatile Salts, I have always doubted, whether these Solutions should not properly be attributed to these Salts; especially, considering that the rubbing in these cases was continued for the space of whole months, in which time, tho' but a very small quantity of Salt was applied at once, yet the aggregate of all together, must be pretty considerable. The most ancient, indeed, of the Alchemists, were of opinion, that all things are produced from Water, and at last are resolved into it; and tell us, that Bodies must be always resolved by principles consentaneous to their origin; and hence have acknowledged Water to be the universal *Menstruum*: But they have never let us into the method of practice that would confirm their Doctrine. Pure Earth, however, perfectly free from every kind of Salt and Sulphur, Water will not dissolve; nor will it attenuate and dilute Glass, Gems, Chrystals, or Stones that are perfectly simple. Hence a great many Bodies of this kind, or compounded of these, it leaves intirely untouched. Hence, therefore, we infer, that Water is not a universal Solvent, but that it is limited to those Bodies which we have enumerated.

Having thus, then, carefully examined the properties of Water, we easily perceive, that it will readily insinuate itself into the invisible, nay, the smallest Pores of a great number of compound Bodies. For as it is very heavy, and consists of Particles that are exceeding subtil, its very great lubricity, and its easy separability into its Elements, will dispose them to penetrate with the greatest ease into the smallest interstices. But the very efficacious power that it has of dissolving such a vast number of Substances, very frequently effects too the resolution of the matter that stops up the Pores of Bodies, and by this means, likewise, it procures itself a passage into them; especially, as its ultimate Elements are exceeding firm and immutable, and hence have a true mechanical vertue, as well as that singular one, which depends upon their contractility.

Water insinuates itself into the Pores of Bodies.

When, therefore, by this power it has insinuated itself into the minute Pores of Bodies, and perfectly penetrated through their whole Substance, it is no wonder that by this addition of new matter, it should increase their weights. And this augmentation in many of them, which have a pretty great attractive power, with regard to Water, is very considerable; as in almost all Salts, the fixed alkaline ones in particular; most Soaps we are acquainted with; even pure fermented Spirits; and many Solids. Hence those Persons who sell by weight, find a considerable advantage in disposing of such kind of Goods in damp cold Weather, when they buy them in hot and dry. And by this means the Chemists have been sometimes deceived, who taking notice of these increments, and decrements of the weights of Bodies, have frequently ascribed them to fictitious causes, when in reality, they depended only upon this addition of Water.

Hence increases their weight.

But as it thus increases the weight of Bodies, so likewise it does frequently their Bulk. Hence, therefore, we perceive, that it does not only take possession of their vacuities, but that it exerts likewise a power by which it separates the solid Elements from one another. This appears to be true by numberless Experiments, but never more evidently than in one made and proposed by the *Academy Del Cimento*. Experiment 184. which because the Book is scarce, you'll give me leave to insert here.

And bulk;

A Cone

Pl. IX.
Fig. 2.

A Cone AB was made of solid Steel, and formed as exactly as possible, and its altitude divided into some equal parts. There was then another Cone CD made of a piece of Wood cut longitudinally out of a Tree, which was hollowed in such a manner, that its internal conical Surface was fitted exactly to the Convex Steel Cone AB, when the wooden Cone CD was dry. This wooden hollow Cone was then made thoroughly wet, and upon this it was swelled so much inwards, that it would no longer admit the Cone AB into its Cavity, which it easily received before: But at the same time too the Cone CB, which when it was dry, went into another hollow Cone, was so swelled outwards, that it could not now be thrust into it. Thus then it appeared to ocular demonstration, that the substance of the Wood was expanded by the Water in all its dimensions. Hence, therefore, there are often produced very extraordinary and surprizing effects, by Water's insinuating itself into dry Bodies, which by this means become bigger, and by expanding themselves, are the causes of incredible alterations.

And then
becomes
concreted
with saline
Bodies.

After Water now is thus intimately mixed with Bodies, that are of a vastly different nature from its own, it is then in a wonderful manner capable of being concreted with them into a Mass, in which one should secretly suspect there was any Water. This we see evidently to be the case, for instance, in common Sea-Salt, by the following method. Take three pound of this Salt, and cautiously decrepitate it with a gentle Fire, till it don't crackle any longer. Then put this decrepitated Salt into a clean earthen Vessel, and setting it upon a strong Fire, make it just ready to melt, and in this state reduce it to a Powder, mix with it three times its weight of Bole, and with a great degree of Heat, draw off an acid Spirit of Sea-Salt; of which you will have some ounces. Separate this Spirit, then, according to *Homburg's* method, into an Acid concentrated into a Chalk, and a Water; and by this means you will procure a true elementary Water, drawn from Salt, which having pass'd a calcining Fire, one would have supposed had parted with all its Water. But the Water which is very surprizing, is here so concreted with these saline Elements, that the dissolution of them is almost insuperable, nor to be effected without this extreme torture of the Fire. And the same is likewise true in *Sal-Gem*, *Fountain-Salt*, and *Nitre*: Not to mention *Alum* and *Vitriol*, which too, if they are first calcined with a gentle Fire, and then reduced to a very dry Powder, will, if they are urged with a strong Fire, yield an exceeding acid Spirit, which may be afterwards separated into an Acid, and a good deal of Water.

And Sul-
phur.

With regard to the driest Sulphur, too, I have often been in doubt, whether that likewise in its substance don't contain a large quantity of Water. Whilst it burns, certainly, it affords a Flame and an acid Spirit; but this Spirit, which is always in a fluid form, may by Art be separated into a pure Water, and an Acid equal to the most condensed Oil of Vitriol. That Acid, therefore, which united with the Vegetable Oil composed the Sulphur, at that very time contained Water in it, and consequently Sulphur, which is an exceeding dry Body, and perfectly combustible, is partly made up of Water, as a constituent Element. I am well apprized, indeed, that it may be imagined, and not without reason, that the Water which lies concealed in Oil of Sulphur *per Campanam*, and is procurable from it, may possibly arise from the Air, whilst the Sulphur is burning; for the moister, and more cloudy the Weather is, when
this

this Oil is made, the more there is always of it. But supposing that this is true, yet Oil of Vitriol, and Sulphur, have always Water in them, whenever they exist; and hence, as Oil of Vitriol enters into the composition of Sulphur, Water must do so too. For this reason, therefore, we conclude, that Water is in reality a constituent part of all Sulphurs and Salts, and there lies concealed, tho' it may be extracted thence by Fire.

But it appears much more incredible, that soft fluid Water should enter into the composition of the hardest driest Bodies, and then adhere to them so tenaciously, as not to discover the least sign of its being there, nor to be separated from them without the extreme force of Fire. Nay, and even then, we are not absolutely sure that all their Water is expelled out of them. For the separate Elements of Water, which are exceeding solid, no ways compressible, immutable, and considerably heavy, when they are once very firmly united with Bodies, become at length concreted with them in such a manner, as scarcely to be separable from them afterwards by any Art, or violence. This singular property of Water, indeed, we have cursorily considered already in the beginning of this Chapter, whilst we were mentioning the universal concurrence of Water in almost all the works of Nature. We shall now, therefore, by undeniable instances make it appear, that the hardest, and heaviest Bodies, owe the cohesion of their parts, in particular, to Water alone, which like a kind of strong *Gluten*, consolidates them with so indissoluble a union, and binds the Elements with so firm a concretion, that no glutinous matter whatever is capable of doing it more efficaciously. And the Water itself being here concreted with these, and connecting them with one another, forms together with them one and the same simple cohering Body, appearing to us to be perfectly simple. This property of Water, now, should, I think, be particularly taken notice of by the Chemists, who upon Examination would find, that this conglutinating power of Water ought not to be less regarded than its dissolving one: And yet this last is very frequently taken under consideration, and discoursed of, the former very rarely: In the first place, then, let us examine *Gypsum*: This is a very soft fine *Calx* of burnt Alabaster, that may be blown away with a breath; and yet if you mix with this a proper quantity of Water, it becomes a ductile Paste, which presently acquires a stoney hardness, nor parts with its Water again without a great deal of difficulty. But consider, again, the fat Potter's Clay which we instanced in formerly: This, when it is perfectly dried, affords a Substance, that may be reduced to an impalpable Powder, that flies about upon the least breath of Wind; nor if it is kept dry, or burnt only with a moderate Fire, will ever become concreted together; but yet, if you work this with a proper quantity of Water, it will become a pliable Paste, which dried by a gentle Heat, and then burnt in a proper Kiln, yields us Vessels that vie with Stones in hardness, and are capable of holding Water. Limestones, or the boney Teguments of Fish, burnt to a *Calx*, produce a loose Powder, that by its volatility is troublesome to the Lungs, nor ever spontaneously grows hard; and yet work it well with a due portion of Water, you will have a Paste, which exposed to the Fire, burns into a Stone. If you mix Sand and Lime together, will these consolidate? Never. Add Water to them, and you have a Mortar, which will so fasten and cement Bricks together, that the union will continue for ages undissolved. And as for the Glues with which we

And earthy
Bodies.

join Bodies together, made of Starch, Flower, and the glutinous Substances of Animals and Fish, these all are rendered fit for the purpose by the mediation of Water. If all these things, then, are properly considered, the opinion of these Chemists don't seem so absurd, who assert that Water is concreted with the very hardest Bodies. Who will venture to deny, that Water helps to produce the solid natural Bodies, who evidently perceives this to be the case in artificial ones? Or who will be obstinate enough to exclude Water from compound Bodies, who sees this necessary to the formation of some of the most firm ones?

And the
most solid
parts of Ani-
mals.

But lastly, let us take a view of the driest, hardest, and those that appear the most solid parts of Animals: I mean their Hair, Hoofs, Horns, Teeth, Bones, Ivory, and the Spines of Fish; shan't you be surprized, now, if I assert, that the terrestrial Elements of these several parts coalesce into a proper hardness, by means of the conglutination of Water? But this is certainly the case: For if any of these, after they have been laid by for years, and are become drier than a Pumice-Stone, are put into a glass Retort, and by a strong Fire separated into a volatile part, and a fixed one, the volatile part will be found far to exceed the other. And this volatile part, now, will be almost all liquid, except the Salt; and this liquid part will be resolvable into an Oil, Salt, and large proportion of Water. Hence therefore it appears, that Water is most intimately united with these hardest parts, and serves to consolidate them together; for when by the extreme force of the Fire the Water is all expelled, there remains nothing but loose Ashes, or brittle Fragments, that cohere so slightly, that they are very easily reduceable to Powder. If these Fragments now, which are always black, are afterwards exposed to an open Fire, they become white, and moulder away, and upon rubbing fall into Ashes. But if you calcine a Bone, till it is perfectly white, with heat quite through, and keep it whole, though exceeding brittle, and cohering very weakly, then, if you throw it into Water, you will hear the Water rush into it with a hissing noise, as if violently attracted into the dry Bone, and it will again restore it to its former weight and hardness, the cohesion being by this means recovered. Hence, therefore, we infer, that though Water does not supply the ultimate matter of which the solid parts of Animals consist, yet, as it performs the Office of a *Gluten* to unite the contiguous Particles together, it so long makes a part of the concrete, increases the bulk, and keeps the parts connected together with a proper union.

Nay in Oils,

But as for Oils, now, what person living could ever have imagined, that these are not only not free from Water, but that they are in a great measure made up of it? And yet the famous *Homborg* has proved by very exact Experiments, that distilled Oils may, by a chemical *Analysis*, be in a great measure resolved into the purest Water. *Hist. de l'Ac. roy. des Sc.* 1703. p. 37. *Du Hamel. Hist. de l'Ac. roy.* p. 372. Here, then, we see, that in a matter particularly inflammable, and looked upon as a true *Pabulum* of Fire, the greatest part of the composition in reality is Water.

And Alco-
hols

Nay, and *Van Helmont* assures us, that the purest, simplest Alcohol itself is, by the attraction of Salt of Tartar, half converted into elementary Water. In burning it, certainly, there is a great deal of latent Water discovers itself, as we took notice before in our History of inflammable Matter p. 189. and following,

following. Whoever, then, is thoroughly apprized of these things, will make no doubt of the extensive distribution of Water, through vast numbers of *Species* of Bodies, and its most firm concretion with them.

But here again we must take care and keep within bounds, if we would not err from the truth: For what has been above delivered with some other considerations has given rise to an opinion among the Chemists, that Water alone is the Matter from which are produced all sensible Bodies. For some of the principal of them have laid it down in their writings, that Water being first rendered exceeding pure by a long continued Frost, and then never thawing again, but by an increasing Cold being condensed, and rendered heavier, would at length be converted into true mountain chrystal. And this they boldly assert to be confirmed by observation in the icy Mountains of *Helvetia*, which look northward, where the Ice never thawing for ages, is said to be thus transformed. Upon which head you may consult *Paracelsus*, and the *Academy del Cimento*. In the mean time, however, this is certain, that Water 40 degrees colder than the greatest observed natural Cold, thaw'd again immediately. Nor can the constriction effected by Cold ever so far condense Ice, as to make it come up in weight to Chrystal, much less to the solidity of a Diamond. It is not at all probable, therefore, that Gems are ever produced from frozen, condensed Water, but that these spring from their proper Seeds, as well as all other Bodies. The great *Verulam* says, indeed, that no nutrition is carried on without Water, p. 656, and that nothing grows without it: But this is true particularly of Animals and Vegetables. In Metals the case appears to be intirely otherwise, unless by Water you will understand Mercury; for the Adepts used to call Mercury the Water of Metals, nay and simply, Water, or their Sea. But who can ever believe, that Water can ever be rendered 14 times heavier than it is, in order to be converted into Mercury? Nay, and in Animals and Vegetables too, though its certainly true, indeed, that Water contributes vastly to the Matter of their Nourishment, and the intimate connexion of their constituent Elements, so that hence they partly consist of true transformed Water; yet it never has appeared, by any certain Experiments, that Water is capable of producing all the parts of these Bodies. I am well apprized of the Experiment of *Van Helmont* on the Willow supported by Water alone, which he so carefully describes, p. 88. 32; and the illustrious *Boyle's* account of the Gourd, and other Vegetables, sprung from Water alone, and increased to a very considerable weight. *Orig. Forms.* p. 165. Whence these great Men have been led to think it evident that the most simple elementary Water, being applied to the living Seeds of these Bodies, is, by their seminal power, transmuted into all the Elements both of Animals and Vegetables; so that hence their whole Substance has its rise from mere simple Water. But this doctrine *Van Helmont* advances and urges, because all Animals and Vegetables, when they are dissolved and cohobated with the Liquor *Alcabeft*, are always changed at last into a mere simple Water, equal in weight to their former Body. As for this *Alcabeft*, however, of *Van Helmont*, I confess I know nothing of the matter, nor have I heard of any person who since him has pretended to be Master of this wonderful Liquor, and to have performed the same Experiments. But be this as it will, by a more accurate inquiry into Nature, it is since evident, that Water, indeed, is the principal Vehicle to convey the Matter of Nourishment to the Bodies both of Ani-

Water how-
ever does not
produce eve-
ry thing.

mals and Vegetables, the Water at the same time not being the Matter itself, but being filled with various heterogeneous Particles that are: For the purest Rain-water always abounds with a great number of Corpuscles, very much resembling the nature of Vegetables: And the more any Water contains of a rich muddy Matter, the more weight it will give the same vegetable growing in it for the same time. But the greatest part of the Water that enters into plants soon exhales out of them again, which perhaps would not have been carried up into the Air, if it had not been received into them; and farther, the pinguious Matter that is mixed with the Water, is found to be consumed, whilst the Vegetation of the Plant is thus carried on in Water, Upon this head see the curious Experiments of the famous Dr. Woodward, *Phil. Trans.* No. 253. p. 193. which were afterwards repeated in the *Royal Academy of Sciences at Paris*. We cannot, however, deny, but that Water is sometimes intimately united with the solid parts of Bodies, so far as it becomes concreted with them into the same Mass; so that in reality it not only performs the office of a Vehicle, but likewise concurs in the composition of some parts both of Vegetables and Animals. And hence the ancient Chemists asserted, that Water is the universal Wine which all Plants, Animals, and Fossils drink. In this sense therefore we may venture to say, that Water is the Matter from whence all things arise, and from which, by the incubation of a pregnant Spirit, they are all produced.

A repulsive
force be-
tween Water
and some Li-
quids.

But there are some Bodies which refuse any conjunction with Water, and if it is brought in contact with them, repel it, but yet without any motion in their proper Substance. Oils, for instance, so strongly resist any union with Water, that if you forcibly mix them together, they will disengage themselves again, collect themselves into orbicular or spheroidal Bodies, and repel the Water from their Mass thus united under the smallest possible Surface. Balsams, Colophonies, and Resins melted with a gentle Heat, have likewise the same property. In these, as I remember at present, there is only this difference, that the more subtil Oils grow, the less they are averse to this union, the thicker they are, the more: And hence, when they come to be rendered exceeding thin, they at last become easily miscible with Water, and then will remain mixed with it for a long time, and that, though the Oils are exceeding pure. This, however, must be understood of Water that does not spontaneously lie concealed in Oils; for concerning this Water we have treated already.

And Solids.

But some solid Bodies, likewise, repel Water, those especially that are exceeding solid, or have a very smooth shining Surface. Thus we observe this property in the Furr of Beasts, the Feathers of Birds, Webbs of Spiders, and Bags, and Silk of Caterpillers, and Silk-worms; particularly if the Animals are in health. I confess, indeed, in all these there is an unctuous matter disposed all over their Surface, that has something of the nature of an Oil, and on this account repels the Water, for which reason, when they are boiled with a sharp Lye, and this is scour'd off, they repel it less than they did before: But still it is observed, that a very smooth surface will have the same effect. Examine plates of Metal, for instance, when they are perfectly polished, and you will find, that Water will not only not adhere to them, but that it will fly from them, whereas they would easily retain it if they were rough. Dry Ivory and Stones imbibe Water with their rough Surface, but when they are very nicely polish'd, they repel it. This, you'll say, perhaps, is owing to the Pores being stopped up

up by the Polish, nor do I deny, but this may help, but even to the very external Surface it won't adhere, now it is polished, to which it would when it was scabrous. Is this, therefore, the reason that the Bodies of Fish, which are so soft, and dissolve so easily, are every where covered with smooth shining Scales, and a pinguious subcutaneous Membrane, that thus they may be able to withstand the effects of the Water, in which they are to live, and in which they so soon dissolve? And does it hence happen, that as soon as ever Fish are dead, their Scales are relaxed, and this oily Substance decays, the Water soon macerates their Bodies, which, had they lived, would have continued firm for a long time? *Act. Lips.* 87. p. 160. *Perault. Ess.* T. III. p. 297.

Having thus, then, examined the general properties of Water, we must now add a few things concerning the different sorts of it, for the service of the Chemist. In the first place, then, let us begin with Rain-water; and this certainly one may properly call the *Lixivium* of the Atmosphere, in which are contained all the *Species* of Corpuscles, that were floating about in it. Of what kind, now, these are, and what great variety there is of them, we have already treated particularly in our History of Air: Let these things, therefore, be consulted from p. 282 to 292. There it appears, that in this Air is dispersed every kind of volatile Bodies. But Bodies are either spontaneously volatile, or become so by Fire, Fermentation, Putrefaction, Mixture, Separation, or Effervescence: And hence Salts, Spirits, Oils, *Sapo's*, Earths, and even Metals themselves, are found there. These, however, will be distributed there in various manners, according to the diversity of the exciting cause, which for the most part is the Fire of the Sun, subterraneous, culinary Fires, or mechanical ones, made use of by Artificers. But this variety that is observed in Rain-water won't depend only upon the exciting cause, but upon the diversity of the Soil too, from which the Fire raises the Particles, and mixes them with it. Nor will the difference in the seasons of the year produce a less alteration in this Water: For we find, that the Vernal, Summer, Autumnal, and Winter Rains differ very much, both in the Matter they contain, and the Effects they produce. Vernal Rain-water, for instance, is particularly disposed to Fermentation: For this is replete with those Bodies which the Winter Cold had locked up in the Earth, and the succeeding warmth now resolves, dissipates into the Air, and mixes with the Rain. But the various alterations of the Weather, likewise, make a very considerable difference too in the Rain that falls at different times. Thus that which comes down after a very long Drought, appears by every character to be quite of another nature from that which falls after the weather has been rainy for a considerable while. To these causes add the Meteors that are frequently observed in the Heavens. The Water that falls with Thunder differs from the rest: Not to mention the Winds that carry the Water of the Air from one place to another; by which means it happens, that when Rain succeeds high Winds that have blown for a good while from one quarter, this is full of the Exhalations proper to places at a very great distance, and brought from thence by the Winds. These various Corpuscles, now, the Winds put in agitation, bring together from opposite places, mix with the Rain, and thus bring about a wonderful Mixture, greatly beneficial often to the Corn and Ground. And hence, as frequent observation teaches us, if the Rain that falls in very hot weather is caught in clean Vessels, and kept in them for some time, it will spontaneously putrify into a fetid, pu-

The nature
of Rain-water
various.

trid Liquor; though, as far as I remember, no body has ever observed Rain-water to grow acid. For my own part, at least, after a great number of trials made in the examination of Water, I have never, I confess, discovered any such thing. But when this Water has thus spontaneously grown putrid, it may be easily rendered wholesome again, and may be drank without being offensive; for if you give it only one boil on the Fire, the Animals that are in it will be destroyed, which, with the rest of the impurities, will subside to the bottom, and then if you make it moderately acid, by adding to it a small quantity of an Acid that is very strong, it will be fit for use. This is found to be of excellent Service under the Equator, and between the Tropics, where the Waters putrify so horribly, and breed such quantities of Insects, and yet must be drank. And for the same reason, a small quantity of Spirit of Vitriol mixed with Water will prevent its growing putrid, and breeding any Animals, and at the same time it will continue wholesome and good. But again, by all the Experiments I have made, I have never been able to raise Rain-water into a fermentation, and so convert it into inflammable Spirits. I have found, however, that in Rain-Water caught in a high, pure place, in clean Vessels, there swim about little pregnant Seeds of a very fine, green, river-weed; for upon keeping this Water in very pure Glasses, there first appeared some very small Corpuscles, discovering themselves by their green colour, which gradually increasing, at last extended themselves to a considerable breadth, and upon examining them with a Microscope, I found them to be perfect little Plants. If you rather believe, that in this case the Seeds fell out of the Air into this Water, the thing will be the same; for then as the Rain falls through the Air, they may come down with it. The invisible Seeds, likewise, of a great many kinds of Mosses being interspersed in the Rain, occasion abundance of little Plants too of this kind springing up in this Water. But much the most numerous, that thus grow in Rain-water, are the *Funguli*, which upon examination with a Microscope are found to be much the finest of all, and in the greatest abundance; but the collection of these to the naked Eye appears disagreeably, and looks like a Slime. These then are the principal Vegetables that properly belong to Rain-water, and which by no caution, hardly, can be kept out of it. In one part of the Year, however, they are in greater plenty than they are in others, and hence, in this respect, they produce some variety. But farther, Rain-water caught in the Spring and Summer Season, has been found tainted, likewise, with the impregnated little Eggs of Insects, and has discovered to the Microscope little Animals produced in it, especially when it has been cherished for a good while by the heat of the Sun, and being openly exposed to the Air. In a little drop of Water, thus circumstantiated, what numberless Animals have often appeared, as we learn from the industrious *Lewenboek*? You begin, therefore, to be sensible, with how little reason Rain-water is looked upon to be pure. But in Rain-water there is nothing more surprizing, than that if the very purest of it is perfectly shut up in a Vessel, it in a short time begins to form small, white Clouds, which increasing in number, and magnitude, grow continually more and more opake, and at last degenerate into a fine, tenacious *Mucus*, and change the Water into a slimy Fluid. Hence, therefore, it comes to pass, that when it stands quiet a good while, it is observed to form itself into numerous filaments, to depolite a feculent Matter, and alter in Colour, Smell, and Taste,

and

and after having passed these changes, to acquire at last the rancid smell, and nauseous, nay sometimes intolerable taste of a vapid, mucilaginous Water. This, then, O ye Chemists, is the true Nature of Rain-water, so far distant from a pure simplicity, and so tainted with various impurities! And yet this is the lightest sort of all that we have amongst us; whilst at the same time all others, in almost every place, are somewhat heavier. And, indeed, this is Water truly distilled by nature; for it is raised from the Surface of the Earth, by the gentle warmth of the Air, and carried to such a height as no chemical distillation can possibly imitate; and it returns out of the same Air, without being in the least rendered impure by any Vessel. On this account, therefore, the Chemists can scarcely by distillation prepare any Water purer than that which Nature thus yields us: This appears very evident, if we will but carefully consider the Water which the Chemist distills; the Vessel in which he performs his Operation; the Fire he makes use of; the small height to which he raises the Water; and the Air through which he carries on his distillation: I say, if we will but consider these things, and compare the natural distillation with this artificial chemical one, we shall not wonder, that distilled Rain-water is not lighter than the natural, but hydrostatically the same, as I have learned by undoubted Experiments. Among all the varieties, now, of Rain-water, that of Snow is found to be the lightest. *Boyl. Med. Hydrost.* p. 134. And this Snow-water, the higher the place it is caught in, as it comes down, the purer and freer it will be from the grosser and heavier Particles, inasmuch as it won't be mixed with these as it falls. And again, if after it has been for a long time very cold and dry, the Water aloft is formed into snowy Flakes by a sharp Frost, then this Snow will be the purest of all, especially if at the same time too the weather has been very calm, so that the purity of the Air has not been disturbed by the admixture of a variety of volatile Corpuscles. When the Snow, therefore, has fallen upon a sandy, barren Mountain, a great way distant from any commerce of mankind, and has perfectly covered the Surface, and is risen to a considerable height, then if you very gently take off only the upper part, this Snow will be as pure as it is possible, either artificially or naturally, to procure it: For in this there will be scarcely any Salt, Air, Oil, or other Bodies. Hence this Snow, when it is melted, yields a Water different from all other. The Water, indeed, of this Snow is the purest of all we are acquainted with, is exceeding immutable, capable of being kept for many years, and is a singular remedy for inflammations of the Eyes. From such pure Snow as this the Alchemists long ago asserted might be extracted, by a secret method, a very red Body, which lies buried and concealed, by an igneous power, in its inmost recesses. And that this Snow, when it falls upon the same place for some ages together, leaves every time a very fine Crust, which in a series of years rises to a considerable *Stratum*, and renders the Soil there extremely fruitful, the famous *Olaus Rudbekius* proves by abundance of arguments, in that infinitely laborious Work, his *Atalantis*. p. 128. Thus much, then, for the method of obtaining the very purest Rain-water. But farther, this Rain-water being digested for a considerable time, putrifies, stinks, and if it is then distilled, yields oily Spirits, that are in some measure inflammable. And being digested, putrified, distilled, and concentrated, it has afforded a very fragrant Spirit, which very gently dissolves the Body of Gold, without any effervescence. *Aët. Lips. An.* 90. p. 86. When it is put into Casks,
and

and by the heat of the weather has putrified between the Tropics, it afterwards loses its stink and putridness, settles, and grows very clear. *Phil. Trans. Abr.* Vol. II. p. 326. The most impure Rain-water, now, of all, is that which falls in very hot and windy weather, and is caught in places about cities that are low and fetid, where Animals, Vegetables, and other Substances, by the vast number of people are perpetually dissipated into the Air; especially if at the same time that Air is foggy, thick, and stinking, so as to affect the Nose with a very disagreeable Smell, and the Lungs with a noxious Vapour; which Stink, as it often comes without any visible cause, so it disappears again in the same manner, without leaving the least mark behind it, and perhaps afterwards returns again as it went. We have likewise observed, that when it has been exceeding hot and dry for a long time, and there succeeds great Thunders, with large showers of Rain, the Water that then falls, if it is collected in pure Vessels, produces a Froth, which seems truly to contain something of a very fine kind of nitrous Salt. And Rain that has come down with terrible Whirlwinds, has been sometimes found to be fetid, and if it fell upon any garment, in the space of four and twenty hours, filled it full of Animals *Phil. Trans.* No. 127. p. 652. Abrid. V. p. 171. Hence, then, we may easily see the reason why this Water is so greatly conducive to the fertility of the Earth, both as it contains a very subtil Matter, which furnishes Particles both for the solid and liquid *Pabulum* of Plants, and at the same time is the most proper Vehicle to carry to them all those Substances which are necessary to their nourishment. If the Water, now, collected from melted Snow, and mentioned before as the purest, is distilled once with a gentle, clear Fire, in tall, clean Vessels, this may be looked upon as the very purest of all, especially if this distillation is performed in a place that is free from Smells and Vapours. After having tried a great many different methods, I have not found any one by which I could render Water more pure than by this. I know, indeed, that some chemists, when they wanted Water exceeding pure, have distilled it very gently off of fixed alkaline Salts; and by this means, it is true, they have fixed all the Acids in the Alkali, and easily retained in it both the oily and the terrestrial Particles, but then, at the same time, there is somewhat of a lixivious quality communicated to the Water. Others, therefore, have distilled these Waters off of *Sal Gem*, Sea Salt, Nitre, and the like; but the Water they obtained by this means was always more impregnated with heterogeneous Particles. Nay, though you distill it successively with different sorts, you won't make it at all purer, as I learned by performing the distillation alternately, with alcalious, acid, and compound Salts. This purest Water, now, when it boils on the Fire, has that fulminating quality which we formerly described, and concerning which we took notice, that it did not depend upon the Air, nor does it ever lose it, though it be ever so pure, and has been distilled some number of times. But it remains farther, that we lay before you those Marks, which in such a manner belong to this purest Rain-water, that they serve to distinguish it from every other sort. In the first place then, if this pure distilled Water is mixed with other Waters less pure, there immediately appears a whiteness upon the mixture, though they both were very clear before. If the best common, or Venice Soap is dissolved in this Water, the solution is perfectly equable, without any small soapy Fragments; whereas,

if you dissolve it in Water less pure, you will observe such little Masses appearing half dissolved, like Milk that is half curdled. If it is poured upon wax, that is to be exposed to the Sun, or thrown upon Linnen that is to be whiten'd, it gives them an exquisite whiteness, whereas that which is impurer leaves them not so clear. Of all Waters, this grows hot and cold again the soonest: But by boiling, it never becomes better. If into this Water, when it is cold, you throw the purest Gold or Silver, when they are perfectly melted, either separately, or together, they pass quietly through it, and fall to the bottom, divided into little grains: This the Assayers call Granulation, and it is of excellent service in a great many chemical Operations. Iron, Tin, and Lead, in fusion thrown into this Water, in the same manner, fly from it with a very violent motion, and a great noise, so that the mixing these with it is much more dangerous. But what a surprizing quality has Water, with respect to melted Copper? Certainly, if you throw this into Water, the Copper, Water and Vessel will be agitated with an incredible noise and fury not to be restrained, to the imminent danger of all around it. Nay, it has been confirmed by very fatal instances, that upon a small quantity of Water's being poured upon this metal, when it was in fusion, every thing about it has been torn to pieces, with an *impetus* almost quicker than that of Gun-powder. This surprizing property, now, I am of Opinion, cannot be understood, or explained, from any common principle of Bodies. In the last place, Rain-water, when it is simple and pure, may be looked upon as the Mercury of Animals, and Vegetables; for then in point of simplicity it is not inferior to the Mercury of Metals. Then, according to *Van Helmont*, it is the first Element, out of which all things are produced, and the last into which they are all resolved. But this doctrine, as we took notice before, must be allowed only with proper restrictions.

All Spring-water owes its origin intirely to Rain-water. For the Heat ^{Spring} raises the Water from the Surface of the Earth, and the Waters, into the Air; ^{Water.} and then the Air, when it is thus replete with watery Vapours, being stopt against the cold, broad tops of high mountains, applies it to them, by which means it is there collected into drops, exactly in the same manner as in our distillations. These drops afterwards uniting together, run down the sides of the mountains, either in little streams on the surface of the ground, or else sinking down into some subterraneous passage, there form a kind of reservoir, and descend from thence. When these places, now, are higher than those where these Waters find an out-let, there the Fountain plays up so much higher in proportion, as these collections of Water are higher than the mouths where they burst out. Hence, then, we see the reasons why there are no Springs, except in the neighbourhood of mountains? Why there are most Springs where the Mountains are most in number, highest, and most solid: And why in Vallies situated between Mountains, Springs are most frequent, and rise highest. Hence, likewise, we understand, that Spring-water can never be more pure than Rain-water, since the purity of the former depends intirely upon the latter. And how, indeed, is it possible it should be more limpid than that Vapour from which, when it was aloft, it took its origin? For, certainly, Water can by no method be purified more than by being carried to such a height in the Air. This Rain-water, however, thus collected into
Spring-

Spring-water, if it happens to fall into places that are full of Flints, then, being detained in their Interstices, and running through them, it there deposits all the heterogeneous Particles it was before tainted with, and at last, having been purified through these Meanders, it becomes pure Water, clearer than Amber. This then is the method which Nature makes use of to bring Water to its greatest clearness, and simplicity; and this is the Water mentioned by *Virgil* as *exercitata cursu*, and described by him as purer than Amber: Nor do I know any other contrivance whatever, by which it can be rendered more pure. But we know, likewise, that our common Sand or Gravel is nothing but a collection of very pure Chrystals, or little Flints. And the figure of these, now, is so vastly irregular, that it is scarce possible to find any two that are perfectly alike. Hence they can never be so placed among one another, as not to leave some empty Spaces between them; and for this reason, if the Water that distills from the Mountains happens to light upon these sandy Gravels, it then running through the small Interstices of the Sand, becomes a good deal more pure than it was before. And hence, too, even Rain itself, falling upon the Surface of sandy Mountains, and then strained through very clear Sand, runs down in form of very pure Water. This Spring-water, however, when it runs through such places as contain Substances that are easily dissoluble in Water, it then in its passage dissolves such Bodies, and carries them along with it. Nor does it at all signify, then, whether it runs through Rocks, Sand, Hills, or Mountains, for it will still retain these dissolved Particles. And hence it comes to pass, that Brooks, Rivers, and Springs acquire the Nature of that Matter, which lies in the Channels through which the Waters pass. For this reason, therefore, nothing can be asserted concerning the particular disposition of Spring-water, till we are acquainted with the nature of the subterraneous Passages through which it runs. A reflexion upon Alums, Salts, *Sapo's*, and Vitriols, makes this sufficiently evident. Thus sometimes it comes out under the name of Chalybeate Waters, called the *Acidulae*, though the egregious *Hoffman* has made it plainly appear, that these are of an alkaliescent, volatile Nature, and are replete with an embryonated Spirit. And often, you see, it appears in sulphureous Baths, vastly different from the former, though they both owe their origin to the same Spring-water. Some Springs again are wholesome, and have a medicinal vertue; whilst others are pernicious and poisonous. Nay, there are some which are endued with a petrifying quality, as is observed in the petrifying Cave in *Burgundy*, about a mile distant from *Quingey*, where the Water, as it drops down, petrifies into statues of all kinds of figures, *Journal des Scav.* 1688. p. 432. And yet what is particularly surprizing, these petrifying Waters don't generate Stones in the human Body. *Mem. de l'Ac. roy. des Sc.* 91, 92. From all these instances, then, it evidently appears, that nothing can be asserted of the clearness, weight, and vertues of Spring-water, that will hold universally true; but we must examine every one particularly, if we would rightly understand its nature. And indeed there is no consideration makes this plainer, than this, that if you boil any sort of Spring-water whatever, for some time, and then let it stand to cool, it will always deposit some *Fæces*. But whilst we are thus examining all the circumstances of Spring-water, there is nothing more particular and extraordinary than that you shall have none of this Water in some places, though you dig to a prodigious depth.

A surprizing instance of this we have given us by the famous Dr. *Plott*, in his description of *Staffordshire*, where he tells us of a Well that appeared by letting down a Line to be 2600 feet deep, tho' it did not then touch the bottom; and yet in all that depth, there was no Water to be met with. How prodigious solid must the bottom of that Well be, to prevent any Water's bubbling up through it? And how very strong and solid must the sides of this Well be from the Surface of the Earth to the depth of two thousand six hundred feet? Consult the famous Author, and *Journ. des Scav.* 1680. p. 14.

River-water should come next under our consideration: But as all Rivers that run with a constant course, owe their origin intirely to Water collected from the Air by Mountains, as we have just now mentioned to be the case of Springs, hence the matter of them both originally will be perfectly the same. In this respect, therefore, every thing that has been said of Spring-water, may be applied to River-water. And the principal difference, indeed, that there is between them, is this, that Spring-water almost always runs underground, whereas River-water being generated on the Mountains, trickles down the sides of them, collects itself into little streams, which gradually uniting together, form Rivulets, and at last terminate in large rapid Rivers, always exposed to the open Air. Hence, therefore, whatever falls from above, whatever is brought by the Wind, whatever is added by Vegetables that fall into them, whatever is brought thither by Animals, or deposited there by Fishes, or amphibious Animals, all these things are collected in Rivers, mixed with their Water, and lodged in them, and there may be macerated, putrified, and at last dissolved. River-water, therefore, besides containing every thing which we mentioned before of Spring-water, may have all these Bodies mixed with it likewise. If you please now to consider, that these Rivers thus coming from the Mountains, let them run ever so far, at last discharge themselves into a Sea that is lower than those Mountains, then you will easily perceive the reason why they never stand still, but constantly keep on their course towards the Sea. Hence, likewise, we understand, that Rivers, whilst they are continually running through so many different places, as Woods, populous Cities, &c. their Water must in every one of these become perpetually of a different nature. For this reason, then, again, we must not pretend to pronounce absolutely concerning the particular nature of River-water, but consider here, likewise, what alteration it continually receives by this addition of new Bodies. The Rain-water, certainly, that comes down from the Clouds, mixes itself with this River-water: As we see likewise Animals, Vegetables, and Fossils, in different places, and times, are dispersed through it likewise. What wonder, therefore, is it, that some Water taken in by the *English* at *St. Iago*, and put into Hogsheads, should be so altered, that when they were about the Island *Borneo*, it should, by the Heat of the Weather, emit a Vapour, which upon a Candle's being apply'd to it, catch'd into a bright Flame? The Water at that time was exceeding fetid, but after it came to settle, it grew very sweet again. *Philos. Trans. Abridgm.* T. V. p. 271. *Thames* Water, put into Casks, stinks, and comes to itself again. And *New London* Water stank prodigiously in eight days time, but being carried to *Virginia*, it again became sweet. *Phil. Trans.* N. 127. p. 652. And again, the same *Thames* Water being put up into Hogsheads, and carried into hot Countries, within the space of 8 Months, was changed into a Liquor abounding

with inflammable Spirits, so that the Vapour of it took Fire like Spirit of Wine. At that time too it stank; but upon the admission of the fresh Air to it on opening the Vessels, the stink was all gone in four and twenty hours; but if the Vessels with their Water were well shook about, it went off in five hours in such a manner, that it was not at all troublesome: And yet this stinking Water when it is drank, is born by the human Body without any inconvenience. *Transf. N.* 268. p. 838. *Transf. Abridg.* T. III. p. 547. *Mem. de l'Ac. Roy. des Scav.* T. I. p. 404. If Sea-water, now, is drawn off by distillation, and is then mixed with River-water, it uses to prevent this putrefaction, as appears by the Experiments of *Du Hamel* upon *Menstruums*, p. 412. But again, in the Kingdom of *Congo*, there is found a Water, the froth of which, if it lights upon Straw, and is then exposed upon the Shore, concretes into a tenacious matter, which when it comes to the Fire, grows hard like Iron. *Aët. Lips.* 1687. p. 650. And the Water of the *Rhone*, if it is first suffered to stand and settle, and is then put up into earthen Vessels, will not putrefy by Heat, tho' it will very much if it is put into wooden ones. *Aët. Lips.* 1683. But farther, upon a careful Examination by Experiments, it has been observed, that Rain, Snow, Spring, and River-water, hydrostatically compared, scarce differ one thousandth part of their weight; and that, tho' some Water from the *Ganges* was tried among the rest. *Boyl. Med. Hydr.* p. 104. Hence we can scarcely understand, or think credible, what is told us by another Author, viz. that there is a Water in some part of *Africa*, which upon an accurate hydrostatical Examination, appeared in the Bulk of one pound to be four ounces lighter than the Water in *England*. *Boyl. Useful. of Phil. Experim.* Part II. p. 114. I wish this surprizing Experiment had been more exactly described, and confirmed by proper authority: The thing certainly is of consequence enough to deserve it: For if this was found to be always the case, then what *Herodotus* tells us of the Water of the long-lived *Ethiopians*, would appear to be perfectly true. But not to grow too prolix, I think what I have said sufficient to let us into the nature of River-water: For it appears to me very evident, that the impurities of such a vast number of Bodies as are mixed with this Water, supply that matter which causes it, when exposed to a great Heat in wooden Vessels, to suffer and undergo all those alterations of Fermentation, and Putrefaction, which we have just now mentioned; which, therefore, are to be ascribed to the contents of those Waters, and not to the Waters themselves.

Standing-
water.

But we must still add a few things concerning the Waters which stagnate in Lakes, Ponds, and Ditches about Towns; for these likewise are frequently made use of by the Chemists. If we consider this sort about our City of *Leyden*, we find it to be a *Lixivium* of all the Privies and Common-shores that are continually discharging themselves into these publick Ditches. At the same time too, vast quantities of materials made use of in dying our Wool, Hair, and Silk, are here dissolved likewise; by which means what a surprizing and confused Mixture must hence arise? Certainly, Alum, Tartar, Vitriols, the Substances that give the Colours, and *Aqua Fortis*, are perpetually running in great abundance from the Dyer's Coppers into this Water. And yet all this Water, now, is either discharged into *Harlemer Meer*, or only gently flows backwards and forwards. Why, therefore, should it seem at all strange, that a good many Articles in dying should be brought to greater perfection here by the help of these Waters, than

than in other places, where they are attempted in the same manner without them? That this is the case, abundance of Experiments confirm. This stagnating Water, now, is a good deal heavier than pure natural Water: For 12 ounces of this Water being put into a glass Basin, and exposed to a gentle Heat, when the Water was exhaled, discover'd at the bottom a great many little Insects of various kinds, and besides, a large quantity of earthy Matter, yellowish, and of a limy nature, together with Mud; which being mixed with *Aqua Fortis*, produced a very strong Effervescence. Various kinds of these Waters, now, being examined hydrostatically by a glass *Index* immersed into them, there appeared to be a considerable difference in their weights, which reduced to a Table was as follows. First, pure Rain-water, catch'd as it fell, was found by this Instrument to be lightest of all, and therefore this was made use of as a standard for the rest. Secondly, Water taken out of the river *Salé*, was one Line heavier than the former. Thirdly, the medicinal Waters at *Hall*, were two Lines heavier. Fourthly, the Spring-water there was four Lines heavier. Fifthly, the Spring-water in the Houses was six Lines heavier. Sixthly, that Water being put into an open Vessel, and let stand a good while in a Cellar, was six Lines and a half heavier. And Seventhly, the Water that stagnated thereabouts in the Ditches and Lakes, was found to be heaviest of all, viz. to be seven Lines heavier than the first Rain-water. All these Experiments made with a great deal of caution, and accuracy, are faithfully related by the egregious *Hoffman*, in his *Exercitationes Physico-Chemicæ*, which can be never sufficiently recommended. How careful, therefore, ought we to be in making Experiments with Water, which appears to be so various; since every sort of it, in regard of its different contents, must so far constantly produce different effects? We ought, therefore, to be acquainted with the methods by which its purity may be discovered, before we make use of it for these purposes. One of the best ways then of trying whether Water is pure, is by a Solution of Silver made in *Aqua Fortis*, and then diluted with the purest Water we can procure: For if you then drop some of this Solution of Silver into any Water you want to examine, if it don't thereupon grow turbid, opaque, or white, you may safely enough depend upon its being very pure, except, that it may contain some Spirit of Nitre, or *Aqua Fortis* in it. In the same manner the best Oil of Tartar *per deliquium*, diluted in a good deal of pure Water, sufficiently demonstrates the purity of the Water under Examination, if upon being mixed with it, it produces no alteration in it; for if there is any thing else in it besides alkaline Bodies, it immediately discovers it by a sudden change of its Colour. But there is nothing in this case more easily affected than a Solution of Sugar of Lead in the purest Water you can get; for if any heterogeneous Water is dropped into this, its impurity appears in an instant. Consult the *Acad. del Cimento*, p. 237, where you will find various valuable Experiments. Such Marks, now, as these, that thus serve for the Examination of Waters, are of infinite service in chemical Inquiries, where there is an incredible nicety required, since the very least admixture of any foreign Matter will often render the whole Operation ineffectual. How often have the Chemists, to their great disappointment, experienced the truth of this, when they have been engaged in raising the *Arbor Dianæ*, or in the chemical Production, and variation of Colours?

Ice, the natural state of Water.

Upon an Examination, now, of what has been said, we are obliged to conceive of Water as a kind of *Species* of Glass which melts in a Heat of 33 degrees, and grows hard in a Cold that is a small matter greater: For it then becomes a hard, elastic, brittle, pellucid, inodorous, and insipid Mass, that may be polished into durable *Lens's* and *Menisci*, for Microscopes, and Burning-glasses. This Glass, it's true, is volatile; but in other respects, is the same as the common. And if we regard it now with proper attention, it is pretty surprizing, that from so soft and fluid a Body as Water, there should in a short time be produced so hard and solid a one as Ice: And that from Corpuscles, which whilst they were in a state of Fluidity, had no signs of elasticity, there should, now they are constringed together, arise a Mass that is exceeding elastic, and which being formed into a Ball, rebounds like Glass, or an elastic Metal. And this hardness, now, and elasticity, thus produced in Ice, increases continually in the same proportion as the Cold increases, so that when at last that comes to be very intense, Water becomes hard like true Glass, and acquires a prodigious elasticity. But this Glass arising from Water, dissolves again in 33 degrees of Heat, and then becomes immediately volatile. Some ingenious Men, indeed, have asserted, that by a strong and lasting Cold, the Particles of Water may be so united together, as to be converted into Chrystals and Gems, that would not melt in a common Glass-house Furnace: But that this opinion is not sufficiently confirmed by proper Experiments, we have taken notice already. If you suppose, however, that this may be true, then Water, by this transformation, would be capable of receiving such a quantity of Fire into it, as to make it red hot, and shine in the dark like Metals, Stones, and other solid Bodies. But so far as we are hitherto acquainted with Water, it is found impossible, by any assistance of Art or Nature, to increase the Heat of it to more than 214 degrees, unless at the same time you compress it with a greater power than common. If, indeed, we could compress Air a thousand times more than it is compressed by a common Atmosphere, in this case, possibly, one might heat it nine thousand degrees farther; which Heat would then be much greater than that of melted Iron. But in the last place, as soon as ever frozen Water is dissolved by the warmth of the Air, all its hardness, elasticity, and brittleness, are at once perfectly destroy'd.

When it thaws, it becomes a Solvent.

And no sooner is Ice acted upon by the very least degree of a Heat that is able to thaw it, but it immediately becomes a *Menstruum*, a moving cause, and the most universal Vehicle, which dissolves, in particular, the more active Bodies, mixes them together, applies them to one another, by uniting itself with many Bodies that are too acrid, renders them more mild, puts all Bodies in agitation, and so produces the most remarkable physical changes, and operations.

In Animals the Vehicle of Aliments.

In Animals, certainly, all Nutrition is carried on intirely by the help of Water. Not, indeed, that the Elements of Water are converted into the very Elements of the animal Body, for this is not so universally agreed on, but without the assistance of Water, the true nutritious Particles can scarcely be convey'd to those parts of the Body that want a supply of Nourishment from them. As Water, therefore, alone, is a proper Vehicle for this purpose, hence, of consequence, Nutrition cannot be brought about without it.

But

But neither is there any such thing as Life itself in Animals, without the concurrence of Water ; for this is the softest, most fluid, and finest part of all our Humours, and penetrates most effectually into all, even the minutest Vessels of the Body. If this is too much diminished, Life itself is soon at an end, the Blood and other Fluids being by no means capable of carrying on the Circulation : Nor is there any known Liquor in Nature that will by any means be able to supply its defect. Hence, therefore, every vital action depends upon Water, as it is this that renders the other Humours fit to circulate through their proper Vessels. Whoever by a very gentle Heat has separated the Water from any animal Juices, either the thickest, or the most diluted, has always found, that this constituted much the greatest part, and disposed the remainder to pass through the Vessels designed for them. And again, if you examine any solid part of the Body, you will find, that likewise owes almost all its aptitude to the actions of Life, to Water alone, which being once removed, it becomes incapable of them immediately.

Nay, and Health itself, which is the greatest perfection of Life, and the exercise of all the actions necessary to it, depend upon, and are effected by Water, more than any thing else. The increase of the Body is brought about principally by Water. Water is the cause of a great many diseases, and a great many are removed by it. Death itself is often occasioned by an excess of Water, but much more frequently by the defect of it. And lastly, Water performs the most happy Cures.

And Health,

And that Water is equally serviceable to the Life, Health, Nutrition, Increase, and other Actions of Vegetables themselves, is very evident from what the famous Dr. Woodward has given us upon this subject, in the *Philosophical Transactions* ; which has been since confirmed by the ingenious Dr. Hales in his *Vegetable Statics*. The whole fruitfulness, certainly, of the Earth, arises from Rain and Snow, by which a fertile Crust is gradually spread over the most barren Sands, and there produces a very black and fruitful Earth: This we learn from the elegant Observations of Olaus Rubekius, whom we have mention'd already. But in *Egypt*, and *Lybia*, where the ground is not much moistened by Dew, or Rain, nor any Rivers arising from Mountains, there, when the Sands are once barren, they always continue so ; particularly, because the Storms of Wind there raise up the Sands in vast Clouds, and thus destroy the first Rudiments of this fruitful Crust. *Verulam. p. 655, 656.*

As also in
Vegetables,

And lastly, Fossils themselves, so long as they remain in the metallic Veins, in appearance of a liquid Juice ; nay, and Metals, whilst they continue in form of a thick, pinguious, ponderous Fluid, and go by the name of a metallic *Gur*, so long they exist in form of a saline unctuous Fluid, and they may then be dissolved in Water, nay, and actually contain in them a diluent Water. Upon this head you may consult the Writers upon Metals, and particularly *Agri-cola*, who is far the chief of them. Certainly, all saline, vitriolic, metallic, concreted Juices confirm the truth of this ; for all these make it evident, that Water is the principal Agent among them, that dilutes, moves, changes, and increases them, and mixes them one amongst another.

And in Fos-
sils.

From what has been said, then, it evidently appears, how surprizingly and universally Water is useful. The most tender, and beautiful Colours of Bodies, certainly, are formed by the concurrence of Water, witness the finest Colours

The uses of
Water for
other purpo-
ses.

lours of Flowers, not to mention numberless other instances. The particular scents of Bodies are chiefly mixed, preserved, and perfected by the admixture and temperament of Water: For in this Vehicle, which is much the properest for this purpose, they are most gratefully distributed. And as for the elegant variety of Tastes, what does this depend upon but Water, which by a due interposition, applies them to the Tongue, and the Palate? The singular, the nutritive, medicinal, medicated, and poisonous qualities of Bodies too, by the concurrence of Water, are rendered active, tho' they were not so before. But again, that the very great hardness and firmness of Bodies depends often upon the interposition of an aqueous *Gluten*, we have already demonstrated. Certainly, Bricks, Tiles, Stones, Bones, Horn, Hair, and Hoofs, were it not for the Water that is in them, would soon be dispersed into a very soft Powder. Nay, and most of the physical actions that Bodies exert one amongst another, are performed by means of Water, and would cease without it. And as this is true of Operations that are excellent in themselves, and are the origins of a great many other actions; hence those of course must depend principally upon Water. An instance will make this plain: The Effervescences produced between Salts and Salts, Salts and Oils, and Salts and solid Bodies, happen then only, when these Salts are so diluted with Water, as to be reduced to a state of fluidity, and so brought into action: For when they are perfectly freed from all their Water, and left quite solid, they then generally are but little active. But we know what a vast many changes and operations arise purely from Effervescences; which therefore all necessarily require the concurrence of Water, in order to their being effected. But if we consider Fermentation, too, the fruitful Spring of so many, and so great physical productions, this certainly, can by no means be brought about without Water. Nay, on the contrary, if Vegetables are deprived of their own Water, they can never possibly be raised to a Fermentation, but will continue unaltered for a long time: But as soon as ever a proper quantity of Water is added to them, and they are exposed to a suitable degree of Heat, and the Air has free admission to them, a fermentation spontaneously succeeds and produces all its effects, which are so very considerable. The putrefaction of Animals, Fish, and Vegetables, never happens neither in Bodies that are dry: For these likewise, if they are intirely freed from their Water, and thus rendered perfectly dry, may be kept for a vast while in a dry Air without corrupting, whereas, if they are moistened with Water, they are soon converted into an intolerable putrid Matter. There are numberless other separations of various Bodies, which are brought about by Water very easily, but can be no ways effected without it: Thus the separation of Salts from Earth and Oils, and the extraction of Alcohol from Refins, and resinous Substances are performed by Water. And on the other hand, the union of a great many Bodies too, depends intirely upon Water, and cannot be obtained without it; of which we have given you a great number of evident instances already. Precipitation, again, which among the chemical Operations is so considerable a one, is performed principally by the mediation of Water. The Sublimation, too, of the precious Oil, procured by distillation from Aromatics, Balsams, Barks, Flowers, Leaves, and Seeds, depends intirely upon the assistance of Water alone: For take away this, and there is no physical or chemical Contrivance by which this beautiful Oil can be obtained pure, and without

without an empyreumatical Taint. But again, Water is the *medium* by which we can certainly distinguish and direct the degrees of Heat from the degree 32, to the degree 212, which it is very difficult to do by any other method. I don't deny, indeed, but that Oil will do the same, nay, and farther too, quite to 600; but in these cases, Water continues always the same, whereas Oil growing continually thicker and thicker, does not afterwards retain the equable increments of the ascending Heat. This now is of vast use in the chemical Art, nor was this known to the ancient Chemists; if it had, they would not have taken such a vast deal of Pains to find a method of raising and keeping up an equable degree of Heat, equal to the vivifying Warmth of a brooding Hen; for this now-a-days may be easily come at, directed, and continued by the help of Water, and a Thermometer. Concerning all these effects of Water, however, that have been mentioned, this is to be remarked, that they will be very different, according to the various degrees of Heat that are applied to it, so that upon every increase of Heat, the effect of Water will constantly vary: But as this is sufficiently evident, I shall not take up your time in explaining it.

But Water now is never observed to be more active, than when by boiling, it is raised into Vapours in a close place; for if Bodies are exposed to such a floating Vapour, and are perfectly moistened by it, they are thence surprizingly penetrated, altered, corrupted, and dissolved. By Experiments, however, that have been made on purpose in this affair, it is certain, that Vapours exhaling from Water by means of a gentle Heat, have this different effect upon Bodies exposed to them, that those that rise from Salt-water make them putrify less, than those from fresh, which destroy them a vast deal sooner; so that hence the putrifying power of the Vapour of fresh Water, by the assistance of Heat, was very evident. The ancient Physicians, therefore, very justly remarked, that a moist and hot Air has a pestilential Quality, and soon dissolves human Bodies. And by the Moderns it has been observed, that the *Europeans* who first settled in *America*, almost all died of a malignant distemper, which in form of a putrid Fever, very soon resolved their Bodies. And this happened particularly to those Persons who lived in the places which were woody; for there the Air is always exceeding moist, and abounds with warm Vapours exhaled by the Trees, and other Vegetables, in incredible quantities. For if you compute, according to the calculation of the ingenious Dr. *Hales*, in his *Vegetable Statics*, the Surface that all the Leaves of a pretty large Tree make up in the Summer time, it will be evident, that there must be a prodigious deal of Water continually exhaling from the Woods in so hot a Climate. And hence, when these Woods were set on fire and destroy'd, and the Country was laid open to the Air, the same places became very healthy. See upon this head the curious Observations of that famous Physician *Ludovic. Testi*, concerning the wholesomeness of the Air of *Venice*. *Aët. Lips. Sup. Pl. III. p. 167.*

The Vapour
of hot Wa-
ter active.

That Water rarifies when it is by Frost congealed into Ice, was first observ'd by the famous *Galilæo*, and consequently, that Ice is rarer and lighter than the same quantity of fluid Water. Hence it comes to pass, that Ice always swims upon Water, the specific gravity of Water being to that of Ice, as 9 to 8. *Experim. of the Acad. del Cimento. 25. 28.*

Ice rarer
than Water.

From aerial
Bubbles.

This rarity, however, of Ice, is owing to Spaces full of Air-Bubbles, which, whilst the Water is freezing, are formed in it, and being considerably large in comparison of the Water, are the cause that the Body of the Ice appears lighter. For in our History of Air and Water it has been abundantly demonstrated, that in cold Water there is a pretty large quantity of Air lodg'd in the Vacuities left between its Elements; which Air, however, not coming at any other aerial Particles, is not collected and united together, nor has any elastic force. But when the Water comes to be constringed by the Cold, by reducing itself into a narrower compass, and lessening its Interstices, it presses out the Elements of Air, unites them together, and hence forms elastic Bubbles, that expand themselves, and become lighter. And as the strength of the Cold grows gradually greater and greater by the association of new ones, these Bubbles grow continually bigger and bigger, and thus increase the proportion of Air, to the bulk of the Ice.

Hence
breaks Vef-
sels.

These now at last being rendered very great, the Air acquires such a prodigious expansive power, that it bursts almost all Vessels, let them be ever so strong in which it is confined; even such as it could scarcely have broken, if it had been dilated by the Heat of boiling Water. Some of the most ingenious among the Philosophers, indeed, have imagined, that this accident happens from the solid parts of the Metal's contracting themselves upon the Ice that is formed within, and consequently, not from the expansion of the Ice outwards, but from this contraction inwards, the Vessel, and the Ice, being in the mean time both condensed by the Cold. But to this ingenious conjecture, the Gentlemen of the learned Academy *del Cimento*, oppose the following evident Experiment. They took a new hollow Sphere of pure Gold, and filled it perfectly full of Water, and having closed it, exposed it to a freezing Cold. At the same time too, having fixed the Sphere, they fitted upon it an exact metal Ring, a little less than a great Circle of the Sphere; which being placed loose upon the Sphere, encompassed it round almost at its center. They then mark'd the place exactly in the Sphere where the edge of the Ring rested; and afterwards, when the Water was frozen, they found, upon examination, that the Surface of the Sphere was so remov'd from the center, and grown so much larger, that the Ring was considerably raised from the great horizontal Circle of the Sphere towards its *Vertex*, the expansion of the Sphere being much greater than the contraction of the Ring, as appeared by comparing it with another Ring that was of the same size, and was not exposed to the Cold.

Ice formed
of Water,
deprived of
Air.

But Water, now, from melted Snow, or that which has been a good while boil'd, freezes more slowly, and at the same time becomes much more solid, rarifies less, and forms much fewer Bubbles whilst it is freezing. *Acad. del Cimento*, p. 163. And very pure Water, kept a good while in the Air-pump, and exposed to a freezing Cold in *Vacuo*, freezes there much sooner than it would have done with its Air in it, and standing in the open Air in the same degree of Cold. The Ice too from Water thus deprived of its Air, has been found to be much harder, heavier, more equable, and more pellucid, than common Ice: So that hence it is certainly evident, that it is the Air which is lodged in the Water, and is collected by the freezing Cold, that produces this rarity and lightness. Nay, upon making some Experiments very carefully in this manner, there was Ice produced, that would not swim upon Water.

Ibid.

Ibid. 171. If in exceeding cold Weather, you pour a fine Powder of Sea-Salt, *Sal-Gem*, Fountain-Salt, or *Sal-Ammoniac*, that is equally cold, upon rasped Ice or Snow, and then rub them together, the very moment they are mix'd, the Salt will begin to dissolve, and at the same time there will arise a greater Cold than was in either of them before, and that always to a certain degree, let the degree of Cold in them before they are mixed be what it will: At least, as far as we have been hitherto able to discover. And this artificial Cold, by a repetition of the same Experiment, may be increased at pleasure. Alcohol of Wine, in the same manner, being poured upon, and mix'd with Ice, increases the Cold. If the pure saline acid Spirits of Sea-Salt, Nitre, *Aqua Fortis*, or *Aqua Regia*, are rubb'd too with Ice, they generate Cold likewise, which will be always so much the intenser, as they are stronger. But of this we treated largely in our History of Fire, whilst we were relating *Fabrenheit's* Experiments for producing the greatest Cold that has hitherto been known.

If a Person, therefore, should in the coldest Weather take the most pure Water, and in the carefulest manner deprive it of all its Air in the most perfect *Vacuum*, and let it freeze there, and afterwards by this contrivance of *Fabrenheit's* cool the Ice as much as possible; then one might procure the hardest, densest, purest, most pellucid, and heaviest Ice, and by this means the physical character of Ice might be determined evidently to the Senses. In the mean time, however, as far as we can judge from what has been experienced, such Ice would dissolve again with a Heat of 32 degrees.

Hence it evidently follows, that the greatest degree of known Cold does not convert pure Water into any kind of Stone, Chrystal, or Gem, tho' this artificial Cold is 40 degrees more intense than the natural one in those places, where it is asserted, that frozen Water is changed into mountain Chrystal. With us, certainly, no increase of Cold in Ice has made it melt with more difficulty, when it has been exposed again to the usual degree of Heat that dissolves it.

The purest Water, now, being poured into a very clean Vessel, and hermetically sealed up in such a manner, that it had not the least communication with the external Air, continued a whole age without any sensible alteration: So that in all that time, it neither hardened into a solid form, nor generated Earth, or any thing else in it, tho' this was tried in the Air at *Rome*, which is pretty warm. *Boyl.* V. I. p. 62. *Du Hamel.* T. IV. p. 109.

Again, if by the help of the Air-pump, you deprive Water as much as possible of its Air, and then whilst it remains so, shake it about in a Vessel, it will emit an infinite number of very small Bubbles, that spring up like sparks of Fire, and have not much the appearance of Air rising out of the Water. Do these very small Bubbles, therefore, when they are united together, form those fulminating non-aerial Bubbles, which appear in Water whilst it boils upon the Fire, after all the Air by long boiling has been expelled out of it? *Du Hamel.* *Demonstr.* p. 395.

But there is nothing now that is more apt to impose upon us, than the quantity of Water in the Air: For the Particles of Water being ranged in a certain position, with regard to one another, are capable of producing very thick black Clouds; and yet the same Water, in greater quantity, and more dense, but disposed in a different manner, shall be so pellucid, that there shall not be

A a a

the

The most perfect Ice.

Not changed by Cold into a Body that remains hard in the Fire.

Water not changed by time.

Contains something more subtil than Air.

Lies often wonderfully concealed where there is a great deal of it.

the least appearance of it. Thus, if we shut our lips pretty close, and blow our breath out very strong, it will scarcely appear; but if with an open mouth we breath it out gently, it forms a very visible little Cloud, if it meets with the cold Air. In the same manner, ones moist Breath, in the Summer-time, is not discernible, though you see it very plainly in the Winter. But of this we treated fully in our History of Fogs and Clouds. Here, therefore, we only give this hint to the Chemists, that, since it so much concerns them, they would learn to make the most accurate Hydrosopes possible, and study, by the help of them, to find out a method of discovering the quantity of Water in the Air, whenever they have a mind. The usefulness of such a knowledge, not to mention any thing else, appears evident from the necessity of knowing what temperature of the Air is most convenient, if you would prepare Oil of Sulphur *per Campanam*, or Oil of Tartar *per Deliquium*, in the best manner.

A Wave of
Water.

If standing Water is not at all ruffled with Wind, it forms a Surface, that disposes it parallel to that of the Earth. If you then throw a heavy Body upon the Surface of this Water, whether it be a great one, or a small one, or whether it falls upon it gently, or with force, this Body, by thus falling into the Water, will with some *impetus* drive out so much of it upon its stagnating Surface, as is equal to the bulk of the Body. This expulsion, therefore, of the Water will successively continue so long as any part of the Body continues above the Surface of the Water, but when once it is quite covered, it then descends equably, nor is afterwards taken notice of. The Water, now, that was raised by the Body immediately returns back again into the place that is left by it as it subsides, by which means there is formed an undulatory Circle upon the Surface of the Water. And this, from the point where the Body falls as a Center, is propagated in greater and greater Waves, always concentric to one another, to a considerable distance. And these Waves are always formed by this Law, that in the space of $8\frac{1}{2}$ seconds, they run through a *radius* of 12 feet from the Centre of their motion; whereas sound runs 1080 feet in one second in the Air; so that a Wave of Air is to a Wave of Water formed in the same time, as 765 is to 1, which is pretty near the proportion of their specific gravities, according to the computation of the famous *De la Hire*. Though such circular Waves, now, arising from different causes and centers, happen to intersect one another, yet each of them still continues on concentric to its proper center; nor are they confounded with one another. And if they happen to meet with a resisting and reflecting obstacle, after their reflexion they proceed on with the same celerity as if they had met with no resistance at all. And, which is still a much greater Paradox, and really surprizing, whether the Wind is with or against them, it makes no difference at all in the propagation of the Waves. See by all means on this head the *Memoirs de Physique*, &c. Ann. 1693, p. 133. These things I thought worth while to take notice of, that they might afford matter of speculation to our Chemists, who are continually forming notions about the harmony of the universe.

Can Water
be converted
into Earth?

If you distill the purest Water with a gentle Fire, and in a very clean Vessel, to a perfect dryness, it will leave a slight spot at the bottom of the Glass. And this will always happen, repeat the Operation ever so often, with the

the same Water, but in fresh Vessels. Nay, and if you pour it back again into the same Vessel, and then distill it again, upon every such distillation the Crust will grow a small matter bigger, till at last it becomes pretty considerable. This Experiment, by the indefatigable industry of the great *Robert Boyle*, was carried on to the two hundredth time, and he tells us in his laborious Treatise of *Original Forms*, that when Water had been thus cautiously distilled 200 times in a glass Vessel with an Alembic, an ounce of it at last produced six drachms of a white, light, insipid Earth, that was fixed, heavy, and insoluble in Water. *Orig. Forms*, p. 259. to 273. Upon the authority of this account, the greatest Philosophers have laid it down as certain, that Water, by simple repeated distillation, may be absolutely transmuted into true Earth. And hence the illustrious *Newton* deduced, that Water thus converted into Earth, might at last be made red hot. *Opt. Lat.* p. 319. Q. 22. With proper deference, however, to these great Men, give me leave to tell you, what I have been able to discover upon a careful examination into this matter. I took some Rain-water that was caught upon our observatory, in Vessels that were very clean, and so placed, that no Rain could be beat into them that first fell any where else: A great quantity of this I put into a large Cucurbit, and with a very gentle Fire of an Athanor, to avoid any Smoke, I distilled it into a very clean Receiver to a perfect dryness. There remained then a white spot at the bottom of the Glass, but incredibly small in proportion to the quantity of Water: And at the same time, though I had with the utmost care luted the Vessels together with a Lute made of Linseed-flower and Water, I found that in this distillation there was a good deal of the Water lost. Hence I confess I can no ways possibly understand how those famous Gentlemen could by any means prevent all the Water's perspiring through the luting of the Vessels, before the same could be distilled two hundred times. But supposing this, whilst we are repeating these distillations, at the same time that the Water passes in form of Vapour out of the Cucurbit through the Alembic into the Receiver, the empty part of the Cucurbit, the Alembic, and the Receiver are full of the common Air of the Elaboratory where this Experiment is made: But this Air is always full of Dust floating about in it, occasioned by the Fires, the draughts of Air, Wind, and people's moving backwards and forwards. That this is the case appears plain from any glass Vessel disposed in the very uppermost parts of such a place, which will be soon covered with Dust. If we consider this carefully, therefore, it will be very evident, that in every distillation there must by this means be a small quantity of Dust added to what was collected before. And if this Operation is repeated too hundred times, there must, on account of the Water's being poured back again, be four hundred such collections of Dust. I don't at all deny, therefore, but that some of the powder so produced is owing to the feculent Corpuscles themselves in the Water, though the greatest part of it I think ought to be ascribed to the Dust in the Air. And when, upon a just calculation, founded on experiment, I compute the quantity both of the Dust arising from the impurity of the Water, and that collected from the Air, I confess I cannot certainly see that any Earth was really generated from the simple Body of the elementary Water in these Operations. And, indeed, there is still so much the more reason to doubt of it, as *Mr. Boyle* repeated the Operation himself but three times, and afterwards took it upon the

authority of a Chemist, that by two hundred distillations, an ounce of Water had yielded six drachms of Earth. I don't at all question, therefore, but every body that is pleased with this kind of inquiries will think that there is somewhat of consequence in the opinion, which I here candidly submit to the examination and correction of the publick. That Water may be concreted with other Substances into a solid Body, arising from this union, I am obliged to believe, for reasons I have given already: But that the Elements of Water, by mere distillation, have ever, without the interposition of a third Body, been so united as to be converted into mere Earth, I have not yet seen sufficiently demonstrated by Experiment, and have learnt by frequent inconveniencies, that we are too apt to neglect in our chemical processes, those heterogeneous Bodies that secretly insinuate themselves, during the Operation. Thus then, Gentlemen, I have laid before you all those things which the modern doctrine furnishes, with certainty, concerning the third universal, chemical instrument, Water. Whether, now, that Water into which the *Alcabeſt* is said ultimately to resolve all Bodies, is the very same with that which we have been treating of, I am not yet, I confess frankly, able to determine. This doubt those persons only are capable of resolving, who are so happy as to be let into such mysteries, the admiration of which is all that is left for us.

Of EARTH.

Definition of
Earth.

Both the Philosophers and Chemists have made use of the term Earth, in treating of the Principles or Elements of which compound Bodies consist. For by this word they designed to express one of those Elements, which in conjunction with the rest makes up these compounds, and qualifies them in a good measure for performing the Operations both of Nature and Art. And if we examine very nicely into the proper signification of the term, as made use of by them, we shall find, that by Earth they meant a simple, hard, friable, fossil Body, fixed in the Fire, but not melting in it, nor dissoluble in Water, Alcohol, Oil, or Air.

Explained.

That the Idea of Body is included in that of Earth, no body, to be sure, will deny, as its Mass is extended into the three dimensions of Body, is perfectly impenetrable, and always gravitates with its own proper weight. But it seemed a more difficult matter to determine, whether or no it ought to be ranked in the class of Fossils: Upon a careful examination, however, of the characters we formerly laid down of the three natural Kingdoms, I should think it ought principally to be referr'd to fossil ones; for more or less Earth is always intermixed with almost every Fossil that we are acquainted with. This I confess in Metals is demonstrated with more difficulty; but in the rest it is discovered very easily, and that in such quantity, that it can scarcely be separated from them, and then, not without a great deal of trouble. The weight of it, besides, is so great, that it exceeds that of Water, Salts, Oils, and vegetable and animal Spirits; and by this means it insinuates itself into the innermost parts of the Earth, so that it is found, and may be dug out of its deepest recesses. And lastly, pure Earth never discovers in its Mass the intermixture of any other Elements, or scarcely any variety. Hence, therefore, it appears, that Earth could hardly be reduced more properly to any kind of Bodies, than that of Fossils. Supposing, then, Earth to be a fossil Matter,
what

what an exceeding simplicity do we discover in it? Certainly, so great a one, that you'll scarcely, in the whole compass of Nature, find a Body that is more simple. For pure Earth, or, as it is called, Virgin Earth, appears so uniform, and homogeneous, that even Metals themselves don't seem to be more so. And when it is perfectly separated from every thing else, then, notwithstanding its exceeding fineness, it is hard and consistent. I confess, indeed, there are harder Bodies; but this, nevertheless, possesses a considerable degree of hardness. The Matter of Earth, in the mean time, appears friable, so long as it continues under the observation of our Senses; as it always readily suffers itself to be reduced to a finer Powder, in which respect it differs widely from true Metals and Gems. In this particular, however, consists its greatest difference, that it remains so fixed and immutable in the most intense Fire, that when it is intirely alone it is not possible to put it in fusion.

If a person catches pure Rain-water, and distills it carefully, he will find some *Fæces* left at the bottom, as we took notice just now in our last article upon Water. If the fæculent Matter thus collected is perfectly dried, and then thoroughly burnt, it will yield some Ashes, which being very accurately freed from all the Salt that is in them, produce a fine pure Earth, which goes by the name of Virgin Earth. For whether this Matter is generated from the Water itself, which is supposed to be changed in this manner; or whether, which is more probable, it is collected from the Air, it produces this very subtil Powder. For the Air, as we observed before, though it is quiet, and contained in a close place, abounds even then with a large quantity of an earthy, and kind of ashy Dust. This appeared evidently in our History of Air, by the consideration of looking obliquely upon the Rays of Light, in a dark Room, and is confirmed by laying a piece of black Silk open there, which will soon be covered with a kind of dusty Crust; which consists chiefly of a fine Earth, which was floating about in the Air. A very considerable part, therefore, of this Powder is Earth, which, by an infinite number of Causes, being rendered exceeding fine, and put into motion, becomes capable of being carried aloft in the Air, particularly, if it happened to be exposed to Wind. There, afterwards, it intimately mixes itself with the falling Dews, Fogs, flying Clouds, Water, Rain, Snow, Hail, Hoar-Frost, and other things, to which it is applied, and with which it becomes closely united. Nor does the fixed nature of the Earth, generated in the distillation of Rain-water, which, as Mr. Boyle observed, would bear the intensest Fire in a crucible, without being changed, or flying off, make at all against what we have asserted, though a person, indeed, might be apt to think with himself, how can such a quality as this be consistent with a Powder's floating about in the Air: But it is one thing, certainly, for a Body to be at rest in a Fire, tho' a very intense one, that is equably applied to it, on all sides; another to be taken away with an unequable motion of the Air, though without a Wind. When a very fine Powder of Earth is placed in a Test, and urged upwards, downwards, and on all sides, and from the center, by the very same Force, it stagnates, if I may so express myself, in a homogeneous Liquid, and by this means continues at rest; but if the puff of a Bellows happens to fall upon this same Powder, it instantly disperses it about: And as Clouds replete with Water are driven about, and the very Waves of the Sea are carried up, and hurried along by the Winds, so we know likewise, that the Sands of *Egypt* and

The most perfect procured by distillation.

and *Lybia* are raised into the Air in such a manner, that they were sufficient to overwhelm *Cambyfes's* whole Army. Gold-Leaf, and very thin Plates of other Metals, bear the greatest force of the Fire, for a considerable time, in the Cupel; and yet are blown away by the Breath, or a very gentle Wind, and dissipated into the Air. We ought to consider, likewise, at the same time, that Bodies that are perfectly terrestrial, so long as they are intirely simple, and unmixed, often continue fixed and unmoved by the Fire, though upon their being mixed with other Substances, they become so volatile, as to suffer themselves to be carried up into the Air, by a moderate Heat. There is nothing, you know more fixed in the Fire than Gold; and yet if you mix it with *Regulus* of Antimony, and then carefully rub it for a considerable time with the best Sublimate of Mercury, you make such an Alteration in it, that it will fly off with a gentle Fire. And so pure Earth, if it is perfectly separated from every thing else, will remain fixed in a Crucible, in the strongest Fire; though if you mix it with other Bodies, you may dissipate it into its ultimate Particles. This we need no other proof of, than the burning of Wood under a high Chimney. Does not the Smoke of this fix a black Soot to the very uppermost part of the Chimney, which, being chemically examined by Fire, yields a large quantity of Earth, which was carried up so high by the Oil and Salt that were mixed with it? And yet this Earth, now, when it is purified, and by itself, you may burn with the strongest Fire, and it will in the midst of the Flames remain perfectly fixed. Thus then you understand where and by what method one may procure the most simple Earth, *viz.* by distillation of the purest Rain-water. But yet even in this case, the *Fæces* that are thus produced, will contain in them every thing that was, together with this Earth, floating about in the Air, and at the same time is not volatile enough to ascend in that degree of Heat with which the distillation is performed.

And by combustion, from the Ashes of Vegetables.

If Vegetables are burnt in an open Fire, they moulder away into white, fixed, fine Ashes, which with the least puff may be blown into a volatile Powder, and be carried by the Wind to a very great distance. Nor has there ever yet been discovered any one Plant that upon burning would not produce such Ashes. If you take, now, these Ashes, and wash them a good many times, and very carefully, with the purest Rain-water, you may by this means perfectly free them from all the fixed Salt that remained in them: And as the Fire before had carried off all the Oil, and volatile Salt, the Earth will at last remain in the Water by itself. These Ashes, then, which will not have the least Saltiness in them, must be shook well together, with some very pure Water, and when this is become turbid, it must be poured off into a clean Vessel, and then more Water must be put upon the *Residuum*, and stirr'd together, and decanted as before, and this must be repeated till all the Ashes are thus washed from the little Stones, Sand, bits of Glass, and other little, solid, heavy Particles, which are not capable of being diluted in the Water. All this turbid, decanted Water, then, must be put into one Vessel, and suffered to stand till all the Ashes have subsided to the bottom; and then you must very carefully pour off the Water, leaving at the bottom a very fine Mud, which if the Salt is perfectly separated, by being dried with a gentle Fire, will give the true elementary Earth, produced from Vegetables by the Chemical Art. This Earth, now, is found to be perfectly inodorous; quite insipid; of a white colour; very soft,

and scarcely sonorous; hardly dissoluble by any means, in Air, Water, Fire, Alcohol, or Oil; so fixed in the Fire, that if it is pure, it can scarcely be converted into Glass; capable, like Flower, of being work'd with Water into a Past that is so ductile, that with care it may be formed into a Vessel, which is able to bear almost the very greatest Torture of the Fire without any damage, will not vitrify in any degree of common Fire but remains unchanged, and will contain in it all kinds of Metals, whilst they are in fusion. This is that Earth which the Assayers make their Tests with, for trying their Metals, when they want to discover what quantity of Gold or Silver is mixed with other fossil Bodies. Of this are formed the Cupels, in which the Fossil Glebes are mixed with melted Lead, by which means they leave their Gold and Silver fus'd into a globular Figure, whilst every thing else is dispersed and carried off. Of this too are made the Mufflers under which these Cupels are placed, to prevent any Dirt's falling into them, and through which there passes a pure and very strong Fire. This is that Earth which being kept ever so long with melted Lead in an intense Fire, is never fused itself, or made to vitrify with it. And lastly, this is the Earth of which is formed that *Mystica Vannus* of *Vulcain*, not of *Bacchus*, through the Pores of which the crude and imperfect Bodies, that vitrify with Lead, are strained, as it were, and run out, whilst not the least Particle of Gold or Silver is admitted through them, which collect themselves, and unite into a globular Mass, in the center as it were of the Test, though its whole Concave Surface and Body are every where, and equally porous. This Earth, therefore, when it is formed into such a Vessel, is the true Sieve of Metals, when they are fused with Lead. All these Characters, then, belong properly to that very pure Earth, which is procured from the Ashes of burnt Vegetables, by the Chemical Art.

The very same sort of Earth, likewise, may be obtained from that part of Vegetables, which in burning ascends from the Fire, in form of Flame, Sparks, Smoke, and Soot: Nor does it at all signify of what kind they are, or whether they are green or dry, acrid or mild. For if the Smoke that fixes upon the very uppermost cold parts of the Chimney, and there forms itself into sooty Flakes, is collected, and exposed to a very strong Fire, in a clean iron Frying-pan, it will fume, take fire, flame, and at last consume into white Ashes, which being freed from their Salt, if they contain any, by the method aforementioned, yield an Earth, which in every property exactly resembles the former, nor can by any means be distinguished from it. Hence therefore we learn how volatile Earth may become, when it is mixed with other Bodies, and rapidly agitated by Flame; to what a great degree of volatility it may by this means arrive; to what a height it may be carried, and so be dispersed and scattered through the Air. When the black Smoke arises from Vegetables, and floats along in form of Clouds, the Earth likewise being there rendered volatile, moves together under the same appearance. But lastly, when Soot is collected, and distilled in a clean glass Retort, with various degrees of Heat, and at different times of the distillation, it yields a Phlegm, Spirits, a volatile Salt, and another Salt, that rises only with the last degree of Fire, and various sorts of Oils; and in the end there remains at the bottom some black *Fæces*, which being burnt in an open Fire, produce Ashes, which when by the help of Water they are perfectly depurated from their Salt, give exactly the very

As likewise
from Smoke
and Soot.

very same Earth as was procured by the foregoing Methods. These last Experiments, therefore, evidently demonstrate, that the force of Fire agitates the very Earth with the Water, Oil, and Salt, and carries it aloft; and that this is perfectly of the same Nature with that which remains in the fix'd Ashes of burnt Vegetables. This indeed is very surprizing, and at first may seem hardly credible, but yet it is absolutely certain, and discovers to us a quality of Earth which before we were not acquainted with. If this Earth, now, which in burning is so volatile in the Soot, as it was first in the Smoke, by distillation, or combustion, is perfectly separated from all the watery, oily, and saline parts that are united with it, it then becomes equally fixed with that which is procured from the Ashes of the same Vegetable when it is burnt. Earth, therefore, when it is perfectly pure, and alone, is exceedingly fixed in the Fire, tho' by being intimately combined with Oils and Salts, it may be very easily rendered volatile. How full therefore must the Air be of a true terrestrial Matter, especially about those places where great quantities of Vegetables are continually burning?

And by Di-
stillation.

But again, take any kind of Vegetable that we are hitherto acquainted with, put it, as Nature produces it, into a clean glass Retort, make a very gentle Fire under it at first, gradually increase it to the greatest degree, so that every thing may come over successively into the Receiver that will rise by those different degrees of Heat, and then this Vegetable will be divided into two distinct parts; one, which will suffer itself to be carried up into the Receiver in form of a distilling Substance, whilst the other remains in the bottom of the Retort, and will bear the utmost force of the Fire without ascending, being a fix'd black Coal, which will continue so for a long time, as *Van Helmont* very justly observed formerly, and *Dr. Hook* has since confirmed by Experiment. The Chemists, indeed, commonly tell us, that the Water, Spirits, Oil, and volatile Salts, come over into the Receiver in form of Liquids, as the volatile parts, whilst the Earth, fix'd Salt, and a small quantity of fix'd Oil remain at the bottom of the Retort. But how far this is true, we must here examine. The volatile, first part, therefore, is always of various sorts, viz. Water, Spirits, an Acid Salt, an Alcaline one, and different kinds of Oils. These all now being mixed and united together, produce a Matter very much resembling the Smoke of Vegetables, and the Soot that arises from it; with this difference, however, that when these are raised by an open Fire, then many more and grosser parts are carried up, than when the same Substance is exposed to the Fire in a close Vessel. And hence it comes to pass, that the very same quantity of vegetable Matter yields a good deal less Ashes, when it is burnt openly, than it leaves Coal and Ashes procurable from it, in the bottom of the Retort, when it has undergone the utmost force of the Fire. If you take now all the parts together that were raised by distillation into the Receiver, and distill them again in a clean Vessel, 'till the *residuum* at the bottom is perfectly dry, there will then always remain a black Coal; for tho' you urge it every so long with the strongest Fire, you will never be able to render it volatile: Fumes, indeed, you may constantly force out of it; but the Coal itself will always continue fix'd in the Vessel, and exceeding black. When you have attempted this, therefore, a good while in vain, take it out, and you will find it light and fungous: Then put it in a clean open Vessel upon a common Fire, and

it will burn, and flame, and by this means will have all its blackness consumed, and will then leave a white Earth, which being perfectly freed from its Salt by the methods before mentioned, will be the very same virgin Earth, as was procured by the former Operations. Hence, therefore, it appears evidently, again, that in the distillation of Vegetables, the Earth rises with the Water, Spirits, Salts, and Oils. If you take now the Oil distilled in this manner, and in a clean Retort, urge it through all the successive degrees of Heat, gradually increased, you will have an Oil in the Receiver purer than the former, and much more penetrating. If you then repeat this Operation for a great number of times, the Oil at length will become so fine, that it will come near to the subtilty of Alcohol; but in every distillation, a great part of it will be dissipated into the Air, and its proper Spirit, which gave it its peculiar smell and taste, will intirely disappear. In the mean time, likewise, in every distillation, there will, at the bottom of the Retort, be generated a black Coal, which never yields any Salt, or can be rendered volatile: And when this again is burnt in an open Fire, it produces white Ashes, and a considerable portion of Earth, always of the same nature. Nor is there any end of this, repeat the distillation ever so often, 'till at length you may collect so large a quantity of it, that the greatest part of the Oil will be converted into a pure simple Earth; as you may see in Mr. Boyle, *Of the Mutability of Principles*.

Corollaries
from these
observations.

Hence, therefore, it is certain, that this Earth may be procur'd from any part of Vegetables whatsoever; and that amongst all the sorts thus produc'd, there is not the least difference that our senses are capable of discovering. Hence too, we learn, that all this Earth, when it is absolutely pure, is so fix'd in the Fire, that it can bear its utmost efforts almost without any alteration; but that, nevertheless, when it is mix'd with other volatile parts of Vegetables, it is together with them carried up by the Fire, and is in that respect so long volatile: This we see, both in the Soot that is generated by burning them in an open Fire, and the parts that rise in distillation in a close Vessel. And again, we observe farther, that there is not any volatile part of Vegetables that renders Earth more volatile, and more easily so, than the Oil: And that among the different sorts of Oil, procurable either by Art or Nature, there is not any one that carries up more Earth with it in distillation, than that last thick pitchy one, that is forced out by the ultimate action of the Fire. And to this, indeed, it seems owing, that these Oils are so very heavy, the large quantity of Earth which they contain, thus increasing their weight: And hence arises likewise their very great tenacity. This is particularly confirmed by this Observation, that these Oils, when the Earth is separated from them by distillation, grow immediately very thin, lighter, and exceeding volatile.

Earth in fix-
ed alkaline
Salts.

But we shall again discover a wonderful origin of pure Earth, if we now take carefully into consideration, the other part of the Ashes of burnt Vegetables, namely, that fix'd alkaline Salt, which in the Water was washed away from the Earth that we just now examined. Any body, indeed, would be apt to imagine here, that there was no Earth at all remaining in this Salt; for the Earth we saw in the preceding Operation, was left undissolved, whilst the Salt was dissolved in the Water, and passed pure through very thick filtering Papers in form of a *Lixivium*: Upon inquiry, however, we shall find to the contrary. To this purpose then, take this *Lixivium*, and first of all,

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by

by suffering it to stand quiet for a long time, let all the terrestrial *faces* subside to the bottom; and by this means, it will be so depurated, as to become as limpid as Water: Let it then be filtered through *Hippocrates's* Sleeve, and let this be repeated till it is grown as clear as Chrystal. This Liquor then, if you examine it with a Microscope ever so nicely, will not discover the least sign of any terrestrial matter. Take then this very pure *Lixivium*, and put it into a clean Vessel, and in a quiet place as free as possible from dust, reduce it to the consistence of a thick Oil; and then in a clean iron Pot, evaporate this thick Liquor to a dryness, keeping it continually stirring with an iron Spatula; and by this means you will procure an exceeding pure fixed alkaline Salt. When this is done, put this Salt into a good clean Crucible, and with a Tile cover it over as close as possible, and in this condition commit it to a very strong Fire till it is melted: Then pour it out into a warm brass Mortar, and with a hot Pestil rub it immediately into a fixed alkaline salt Powder. Let this Powder then be put into a large glass Basin, and be thus exposed to the Air in a place free from dust, and the Salt in a very short time will be intirely dissolved into a Liquor perfectly fluid, whilst to the bottom there will fall a white terrestrial Powder, which being thoroughly washed from the Salt that adheres to it, will appear to be nothing but mere Earth, such exactly as the other, which remained in the Ashes. If you take now this Oil of Tartar *per deliquium*, and dry it, calcine it, and expose it to the Air as before, it will dissolve again, and you will have a new Oil *per deliquium*, and always some Earth remaining; and if you repeat the Operation a vast number of times, at length the greatest part of the fixed alkaline Salt will be reduced to a mere simple Earth, that in burning was united with that other Principle, which in conjunction with it, formed the alkaline Salt; which saline Principle being now by many calcinations and solutions separated from its Earth, and set at liberty, flies off, and is dissipated into the Air, and leaves the Earth alone. If you collect, however, all this Earth together, and weigh it, you will find it a good deal lighter than the Salt was at first; this decrease in its weight, evidently evincing, that a great part of the Salt was rendered volatile, and thus carried off. As this Experiment, therefore, constantly succeeds in this manner, we cannot but conclude, that this Earth, thus discovered, did really exist before in the fixed alkaline Salt from which it is by this means procured, and that in so latent a form, that it suffered itself, during that time, to be perfectly dissolved in Water, which otherwise is so repugnant to the nature of Earth. And hence, therefore, it likewise appears, that the purest Earth, when it is united with some other Principle, is totally dissoluble in Water, tho' it is by no means so when it is alone: Unless, perhaps, you will rather believe, that the very Salt itself, not terrestrial before, may, whilst it undergoes these calcinations and solutions, by an actual transmutation, be converted into true Earth. This opinion, however, is not founded upon any Argument or Experiment that I am acquainted with, and therefore seems intirely precarious: And besides, it seems to me to be inconsistent with the settled constancy of Nature, which for so many ages has always been observed to act in the same manner, and by the same means; inasmuch, it has never yet appeared, that any one Element has prevailed upon another, but that being properly adjusted together, they have all constantly remained in the very same proportion. And

And as for the other Opinion, that Earth, by being united with saline Principles, may be rendered capable of being dissolved by Water into a Liquor, in which nothing at all earthy shall appear, this is every where warranted by the chemical Art. In Glass, is not Earth intimately concentered with an alkaline Salt, and thus produces with it a perfect transparent Mass? Which nevertheless, according to *Van Helmont*, may be again resolved into an Alkali, and an Earth precipitated from it. Do not all Metals, when united with their proper dissolvent Acids, appear in Water in the form of a very pellucid Salt? Which, notwithstanding, may be thence again procured opaque, intire, and without alteration: 'Tis needless to mention Chalk, Stones, Oyfter-shells, Earths, and other Bodies; all which, by being combined with Salts, seem to be converted themselves into very pure Salts, which yet by various methods, may be again resolved into their solvent Liquors, and an Earth which is separated from them. How evidently is this evinced by chemical Precipitations? From the abovementioned Experiments, therefore, it is certain, 1. That the common fix'd alkaline Salts, procured from the Ashes of burnt Vegetables, do consist in a great measure of true, simple, elementary Earth, which whilst they are forming, enters into their composition. 2. That this Earth is so concealed, intermixed, and dissolved in these Salts, so long as they exist in a fixed alkaline form, that it does not give the least indication of itself by any sign whatever, and therefore so long cannot be discovered; as it will by Water, or the moisture of the Air, be so dissolv'd, as to be converted into an exceeding simple limpid Liquor. 3. That this Earth of Vegetables can only be subtiliz'd to this degree, by the most violent action of an open Fire, which whilst it is thus consuming Vegetables, so intimately unites this Earth, attenuated at the same time with another alkaline saline Principle, that from both of them thus conjoined, there is generated an Alkali, which is a proper creature of the Fire. And this, now, as we just mentioned, will only happen in the open Air; for a Coal, made from green Wood, being included in an iron Box, was in this manner exposed for several hours to a very strong Fire, and nevertheless continued a very black Coal, nor would yield any fix'd alkaline Salt, tho' upon being afterwards taken out, and burnt to Ashes in an open Fire, its Ashes then afforded some. Hence, therefore, it appears evident, that this Salt does not in reality pre-exist in Vegetables, but is then only introduced into Nature, when the Fire has united Earth to that other Principle, which may be thus combined with it in the open Air, but not in a close Vessel. And that this fix'd alkaline Salt is generated only in the open Air, and by the power of the Fire alone, is not less certainly confirmed by this consideration, that if any Vegetable whatever, is only so far burnt, either in the open Air, or a close Vessel, as to be converted into a black Coal; then, if you reduce this black Coal to Powder, and boil it in Water, it will not, in the *Lixivium*, afford any fixed alkaline Salt: And yet if afterwards you take either this Coal, or its Powder, and burn it in an open Fire, by boiling its Ashes, you will be able from them to procure it. The Earth of Vegetables, therefore, being vastly attenuated by the extreme force of an open Fire, is after the consumption of the Oil, intimately united with the other saline part, and thus produces a fixed Alkali. Nor has this Salt ever any other origin that we are acquainted with.

4. Fixed alkaline Salts, therefore, are not simple Bodies, but are compounded

of two perfectly distinct Principles, intimately united together. 5. And it is likewise exceeding probable, that this burning of Vegetables, after it has attenuated the Earth, combines it with that native Salt, which was naturally in the Plant, and existed there in form of a *Sapo*, made up of this Salt and an Oil united together. And hence we suppose the action of the Fire consumes the greatest part of this Oil, and then converts the Salt, the Earth, and a tenacious black Oil, into a black Coal, in which the saline part lies so concealed under the Oil and Earth, that it does not appear there as a Salt dissolvable in Water, but remains secure from the action of this *Menstruum*, till by a longer continuance, and greater strength of Fire, the black Oil of the Coal is destroy'd, and thus this Oil, which served as a *vinculum* to bind together the Earth and Salt, is removed: And thus we imagine, that at length this saline part, which before was of itself considerably volatile, becomes fixed and united with this ultimate, subtil Earth, being now perfectly freed from its principle Oil. And hence it seems to come to pass, that this fixed alkaline Salt itself, if it is kept for a long time in a very intense Heat, will at last become volatile, and perish in the Fire, tho' if it is mixed in a certain proportion with Ashes or Earth, it will be converted into Glass, which is considerably fixed there, and is very durable. 6. Hence, therefore, we never find any simple Salt in Vegetables, which of itself is naturally fixed, that which is so, owing its fixity intirely to the Earth, with which the Fire has combined it; for if Vegetables are exposed for a great length of time to the alternate vicissitudes of moisture and dryness in the Air, or if they first perfectly putrify, then, if they are afterwards burnt, they won't produce any fixed alkaline Salt in their Ashes. 7. And hence these fixed alkaline Salts, generated in the manner just explained, may, by the contrivance abovementioned, be again resolved into those two Principles, from which they were first formed by the action of the Fire, namely, into a pure, simple, imperceptible, volatile Salt, and a very subtil, pure, inactive, fixed Earth. 8. From this History, therefore, of Earth, it appears vastly more probable, that these Salts are thus generated from this Earth, and a saline Principle, than that Water, by being intimately united with the Earth, should be converted into an Alkali; for tho' all the contrivances within the compass of the chemical Art, are made use of to combine Earth and Water together, it never has appeared, that a fixed alkaline Salt has been thence produced, let the Fire be ever so intense. 9. This Earth, therefore, which is always, and every where the very same, is extracted from Plants in great quantities with the Water, Spirits, volatile and fixed Salts, and Oils, when they come under the management of the Chemist. And as for all the other Principles, the Water excepted, when they come once to be perfectly freed from their Earth, they are so attenuated, and become so active and volatile, that through this vast subtilty, they intirely escape all farther cognizance of our senses, and are scarcely afterwards to be confined in any Vessels, but return into their former aerial Chaos. The Water only, and solid Earth at last remain behind; all the rest quite disappear. The most ancient of the Chemists, therefore, were absolutely in the right, when they asserted, that the Spirits are held fast, that they may not fly off, by Oils, or Sulphur; that it is Earth alone that retains the Sulphur and Salts; and that, therefore, their fixity is to be attributed to the Earth. Thus, then, Gentlemen, from what has been said, we are come to a sufficient certainty about the nature of that Earth, which is found in the class of Vegetables;

tables; which, as it evidently appears to be perfectly the same in every kind of Vegetable, constitutes, perhaps, an immutable Element.

Let us now, therefore, proceed to examine this Earth in the Animal Kingdom. It has always been observed then, that all Animals, of what kind soever, whether they fly in the Air, swim in the Water, or live upon the Earth, or within it, if they are exposed to a warm moist Air, presently putrify after they are dead, in a Heat less than that of a Man in Health. And by this putrefaction, they are in a short time so much altered, that their whole Bodies are resolved into a most fetid putrid matter, which is so volatile, that it is dissipated into the Air, there remaining only a small portion of a firm solid substance behind. Whole Elephants left dead on the ground in hot Countries, and vast Whales thrown up upon the Shore, are soon consumed, their bare Bones only being left behind, whilst all the other parts are carried aloft. As for Camels too, Dromedaries, Horses, and human Bodies left unburied, after the carnage of Battles, it's surprizing how soon there appears nothing of them at all but their Bones. Certainly, the Water, Spirits, Oil, and Salt, are dispersed in such a manner, that there is nothing but a little simple unactive terrestrial Matter left behind: And then this Earth is exceedingly like that which we have just now been examining in Rain-water, and Vegetables. But why should we insist upon this any further, when we see it so evidently in the burying places of very populous Cities, where the Bodies that are buried are resolved into so small a quantity of Earth, that they hardly raise the ground at all? All the parts, therefore, both solid and fluid, of which Animals consist, and into which they may be again resolved by the action of the Air alone, are of so volatile a nature, that they intirely exhale, the Earth being the only part that remains fix'd, and is not dissipated with the rest. And this terrestrial part, if we examine it more nearly, presents to us only mere Bones, or a little Ashes, which are dispersed with a slight Wind and disappear.

Earth in putrified Animals.

But the nature of our design leads us to examine this Earth in Animals still more nicely. Let us first, therefore, take into consideration any of the Humours of any kind of Animal whatever, after, by a due circulation, they have been quite changed from the crude disposition they had when they were taken into the Body, and by the natural powers of the Animal, are assimilated to its peculiar Nature. These then, under this Limitation, being put into a clean Retort accurately fitted, and luted to a Receiver, and exposed to a Fire very gradually increased from a very gentle one to the greatest, will in a Heat raised to 212 degrees yield, first, an incredible quantity of Water; such a one as no-body could ever imagine should enter into the composition of the animal Fluids. If you continue this degree of Heat for a considerable time, all the Water that is thus distill'd from these Humours, seems in most of its properties to be almost the same with that which is drawn from Vegetables, and was before considered; indeed, to such a degree, that we find but little difference. There is, it's true, in this Water from Animals, somewhat of a subtil rancid Smell, and a disagreeable Taste; but these, as they don't discover the least sign of any Earth, have nothing to do with our present Enquiry. If you proceed then to urge the *residuum* with a stronger Fire, when all the aqueous part has been drawn off by the Heat of boiling Water, then this Mass, which is always dry, and in some measure slightly burnt, will yield a light, yellow, Li-

And in their humours distilled.

quor,

quor, less volatile than the first Water, which has been called the Spirit of these animal Humours. This now is fetid, and of so saline a nature, that upon mixing with Acids, it will cause an Effervescence. If you collect then, this Spirit carefully by itself, and distill it in a clean Vessel, it will produce some *feces*, which being burnt, and depurated, as before, yield a small quantity of Earth, perfectly of the same nature with the former; so that this Earth rises with this Fluid, and may be procured from it. If the Mass, then, of these Humours, thus deprived of their Spirit by its proper degree of Heat, is still exposed to a greater Heat, you will have from it distilled animal Oils in great abundance. But if you distill these again in a clean Vessel, they likewise will leave at the bottom of the Retort a large quantity of fixed Earth, as we took notice in the distill'd Oils of Vegetables. And thus, likewise, will these Oils, by a reiterated distillation, be converted into Earth, till at last there will remain only an exceeding subtil Oil thus freed from its Earth, which is almost of a spirituous nature: So that the thickness, tenacity, and fixity of these Oils too, ought to be attributed, as before in Vegetables, to this very same Earth. And as for the volatile Salt of Animals, which partly is forced out of them by the Fire together with these Oils, and partly rises afterwards, and is separated by itself, this always in the beginning of its production has a large quantity of Oil united with it, which by its viscidness, holds down, fixes, and retains it; for as soon as ever you have, by the chemical Art, perfectly freed this Salt from its Oil, it immediately becomes perfectly volatile, and in distillation leaves no *feces* behind it. After the sublimation, indeed, is made with a very moderate Fire, there remains at the bottom an unactive Water, which, let the Salt appear ever so dry, adheres to it so closely, that in a gentle Sublimation, it always discovers itself in this manner, nor can scarcely be perfectly separated from by any contrivance whatsoever. All the fixity, therefore, of the native animal Salts, seems to be owing intirely to an Oil which is naturally in them, and serves to retain the saline parts; but this very Oil owes all its fixity and tenacity to the Earth with which it is united; and consequently, the Earth is, in reality, the *Vinculum* by which the volatile Salt is secured, and held down, which would otherwise be of too volatile a nature: When the former Oils are thus drawn off, if you still proceed to increase your Fire, you will then have a very black, thick, pitchy, tenacious Oil, which will often puff up, and fill the whole neck of the Retort, and thus in form of an inflated Pitch, pass into the Receiver, being heavier than any of the Liquors that were drawn from the Vegetable in the former distillations. If you take now this last Oil, and distill it carefully, and according to Art, the greatest part of it will remain an Earth at the bottom of the Retort, tho' you urge it with ever so strong a Fire. And if you repeat this distillation again, and again, the Oil will every time become more and more limpid, and there will always a large quantity of Earth be left behind. By such a tedious rectification of this, I reduc'd, formerly, some pounds of a thick Oil of Hartshorn, into a very thin, pellucid, volatile Oil, and a large quantity of a black oily Earth, which being burnt in an open Fire, yielded the very same Earth, which we have already so often mentioned. By this means, then, I became certain, that when this last Oil, very tenaciously adhering to the Earth, was raised by the most violent action of the Fire, it carried likewise this Earth along with it; and consequently,

consequently, that though we call this Substance Oil, yet, in reality, a great part of it is only mere Earth. Hence, then, we learn, that Fire, when it is applied to Oils united with Earth, is so far capable of rendering the Earth volatile: And again, that the properties peculiar to this Oil that rises only with this intense degree of Heat, almost all depend upon the Earth, and not upon the Oil itself. Hence, for instance, arises its very great degree of fixity, thickness, tenacity, and weight; all which it loses, as soon as ever it is perfectly separated from its large quantity of Earth. And hence, likewise, we discover farther, the intimate, and almost inseparable union of this Earth, with all the animal Oils, and the constant effect produced by this union, viz. the prevention of their being volatile; for as on the one hand, the Oils, by being united with the Earth, render it, in some measure, volatile in the Fire; so this, on the other, by this same union, prevents their being rendered too volatile, by a small degree of Heat. And as the very volatile Spirits are intangled, and held down by the Oils; so the Oils, which would otherwise rise too easily, are retained by the fixity of the Earth. But lastly, if the fixed, black *Fæces*, that remain at the bottom, after all the Oil is expelled by the former degree of Fire, applied for a good while, are urged with the greatest degree of Heat, and this is kept up for a long time, they will at length emit some blue, shining, dense Fumes, and throw out, at the same time, some sparkling Corpuscles, which, being received into pure cold Water, will be condensed, and by their weight sink to the bottom, where being collected in little Masses, they produce the Phosphorus, now called the Solid, as the former, whilst it floated about in the form of a Fume, may be called the Fluid. This Phosphorus, now, if it is exposed to the Air, takes fire, consumes in appearance of a little lucid Flame, and flies off with a fetid Smell; but even then it leaves behind it a very acid, thick Water, in which there is always something of terrestrial *Fæces*. Of this wonderful Substance, now, we may very reasonably inquire, whether it is, in reality, of the animal or vegetable kind? Or whether it is properly a Creature of the Fire? Or whether it don't owe its origin to all three together? This is certain, it burns perfectly, it will keep for years in Water without being dissolved, and at the bottom of Water it will by Heat be melted like Wax. It rather, therefore, seems to be of an oily nature, than a saline, or terrestrial one; and yet it is perfectly different from every thing that has hitherto been ranked among the Oils or oily Substances, and contains but a small quantity of Earth.

If we examine, now, the ultimate *Fæces* that remain after all the different parts above-mentioned are drawn off, we find them still to continue black; but if the Mass is taken out gently, and burnt in an open Fire, it becomes white, of an earthy nature, retaining its former figure.† This History, then, of Animals and Vegetables, given with a view particularly of coming at the true nature of Earth, lets us see, at the same time, that these two kinds of Bodies appear to be vastly near a-kin in all their properties, and in a great many of them to agree intirely. Hence, therefore, it is no wonder, that Animals, by means of their concoctive faculties, can subsist intirely upon Vegetables, with the simple addition of Water. And as this appears to be every where the case, the bodies of Animals seem almost, in many instances,

The likeness
between
Animals and
Vegetables.

stances, to be nothing but transmuted Vegetables. The chief difference, indeed, between them seems to lie in their Salts; for these, when thoroughly concocted, and so become proper to particular Vegetables, are in many of them acid, or austere; whereas I have never been able to discover any acid ones, much less austere ones, in the native humours of Animals. Let me caution you, however, that this must not be understood of crude Juices, just taken into the Body, and still retaining their own proper qualities; but of such as by the natural virtue of the animal Body, have been truly assimilated to the animal Nature. But again, the Salts of most Vegetables, procured from them by burning, are found to be fixed; whereas there was never any fixed alkaline Salt discovered in Animals, when treated after the same manner; though, as I shall demonstrate hereafter, there are Vegetables that have a volatile, alkaline Salt, like that of Animals, as appears in the Scurvy-grass, Mustard, and others. But the Earth itself, or the Oils, as they contain a large quantity of Earth in them, seem, by their admixture, to cause the chief difference that there is in the fixity of the animal and vegetable Salts: And hence it seems likewise to follow, that the Earth in Animals exists in less quantity, and is less intimately united with their Oils and Salts, than it is in Vegetables.

The putrefaction of Vegetables separates their Earth from them.

Let us, however, consider, in the mean time, that the perfect putrefaction of Vegetables makes such an alteration in their proper disposition, that the Earth being, by this means, more disengaged, recedes, both from their oily and saline parts, and thus effects, that Vegetables, which before putrefaction yielded, in burning, a large quantity of a fixed, alkaline Salt, being burnt afterwards, afford none at all, but then give out all their Salt, of a volatile nature, as Animals do. The union, therefore, of elementary Earth, with all the other Elements of Vegetables, is dissolved by no action more easily than it is by means of putrefaction, which very powerfully divides and separates their Elements from one another, and thus destroys their former particular form, by which means, those both of Animals and Vegetables become nearly the same. And hence it comes to pass, that this very putrefaction renders the Bodies of Animals and Vegetables exceeding fit to produce such a matter in the Air, Water, and Earth, as shall be rightly disposed to yield a kindly nourishment to new Vegetables, and so again, through their means, to Animals. On this account, therefore, all putrefied Substances are particularly serviceable in fructifying the Earth; and for this reason, all Animals whatever, are, by the grand Law of Nature, subject to putrefaction, sooner or later, and thus afford fresh matter for impregnating their Mother Earth, and replenishing it with new fruitfulness.

Fermentation does not separate this earth.

Since, therefore, the putrefaction of Animals and Vegetables thus separates the Earth from the other Elements, and by this means renders them so volatile; hence, perhaps, some persons may be ready to infer, that fermentation, likewise, will do the same. But this happens quite otherwise: For though fermentation agitates Vegetables so powerfully, and for so long a time, yet it is never able thus to free the elementary Earth from its Salt and Oil. And for this reason it does not so assimilate Vegetables to Animals as putrefaction does; nor prevents their yielding a fixed Salt in their Ashes, if they are afterwards burnt; as evidently appears in Tartar. One sort, indeed, of the vegetable Oils it converts into a volatile Alkali, but is not able to change all the oily parts

parts of it in the same manner. From such a number of Experiments, then, we understand the nature of that elementary Earth which enters into the composition of Animals and Vegetables, as a true principle. And in both these, this Earth seems to be perfectly of the same nature, there being very little difference observed in it. This no where appears more evident than in the Cupels, which are made equally good from the Ashes of Vegetables, or the pure Earth of Animals; and that, whether it is procured from Fishes, Birds, Beasts, their Bones, Hoofs, Flesh, or Juices, provided the Earth is but pure. See *Laz. Esker*, where he treats of this subject. This Earth, therefore, serves in the same capacity, both in Animals and Vegetables, gives a firm make to their Bodies, and affords a solid *Basis* for the rest of the Elements; for these must all be united with this Earth, that by this means they may be fixed, and held together, and thus reduced into the shape of any particular solid Body. This Earth alone gives to them all their proper form; and when this is separated from them, they all sink down into an irregular Mass, or being resolved, and set at liberty, become volatile, and are dispersed from one another. This Earth, by its fixity and tenacity, proves a proper *Vinculum* to bind, associate, and properly dispose all the other parts with one another, and so hardens the Body that arises from this conjunction, that by this means it becomes capable of resisting the Air, Water, Sun, and some degree of Fire itself, without suffering any inconvenience. But then, likewise, on the other hand, pure, dry, elementary Earth stands in need of the assistance of Water, or Oil, as a kind of Cement, to hold together its separate Elements, and thus to form them into one Mass.

If whole Animals are burnt in an open Fire, till they are intirely consumed, there then remains nothing but white Ashes, which being pounded, exhibit again an Earth exceedingly like the former, and free from all Oil or Salt. This can no ways be distinguished from the Earth procured from Animals, by the former operations, and serves absolutely for the very same purpose in every kind of Experiment.

The Earth
of Animals
by combusti-
on.

But it is time, now, that we take a view of the fossil Kingdom, and see what Earth we are capable of discovering there. And here the native Salts, Nitre, *Sal-Gem*, Fountain Salt, and Sea Salt, first offer themselves to our observation. Take these, then, as pure as they can possibly be procured, dissolve them in very clean Water, and digest them for a long space of time in Vessels accurately closed, and they will yield an Earth at the bottom, precipitated from them, which will not be dissolved in the Water. When the Liquor is thus depurated, and grown exceeding clear, let it exhale in a place free from Dust, till you observe a Pellicle on its Surface; then remove it into a low, cool, quiet place, and it will shoot into little saline Glebes, of a particular figure, pellucid, and pure, which the Artists call Chrystals, and these, if they are thus carefully prepared, produce a particular *Species* of Salt perfectly distinct from every other. If the Liquor then that remains after the Salts are thus formed, is gently poured from them, it may be again inspissated to a pellicle, and by the same method as above it will generate fresh saline Chrystals, but not so transparent, or pure, as the former. If you, then, as before, separate the remaining Liquor, and proceed in the same manner, after the last chrySTALLIZATION, there will be left a fat saline Liquor, that will not be dried

Earth in
Fossils; first
in Salts by
solution.

without a great deal of difficulty, but then will produce some Earth: And this Mass, when you have rendered it dry by the Fire, will again spontaneously dissolve in the Air, and be of an acrid austere nature. If you take then the Chrystals thus procur'd, and dissolve them, and proceed as before, you will every Operation have some more pure Earth, which being collected together, will produce a large quantity thus generated from the pure fossil Salt. And at last, after this ChrySTALLIZATION and Solution has been repeated a great number of times, all the Salt will become volatile, be dissipated into the Air, and escape any farther notice of our Senses; and of the whole Mass of Salt, which has thus passed under Examination, the Operator will have nothing left but mere Earth; for all the other parts, which in conjunction with this Earth, made up before the Body of the Salt, being by these Operations separated from it, grow so subtil, as not to fall under our Observation, and so volatile, that they cannot remain at rest, but fly away. These Experiments concerning the nature of Earth in Fossils, were known and describ'd by the ancient Chemists, and have been since performed and confirmed by the Moderns. See *Du Hamel Hist. de l'Ac. Roy. des Sc.* 1701. p. 16, 17.

By Distillation.

But again, if you take any one of the abovementioned Salts pure, and very dry, reduce it to Powder, and accurately mix it with three times its weight of very dry Clay, Bole, Brick-duft, or pure Earth, and then urge it with the greatest degree of Fire, it will by this means be resolved into a liquid part, which will be volatile, acid, and corrosive, and a fixed one, which will remain at the bottom of the Vessel in the Earth with which it was mixed. This fixed part, now, if, by boiling it in Water, and letting the Water settle, and afterwards filtering it, you perfectly depurate it, and then reduce it to Chrystals, will yield a Salt pretty much resembling that which was made use of in the distillation, except, that that from the Nitre will be in some measure alcallescent. And if the Salt thus generated, is again dissolved, inspissated, and chrySTALLIZ'd according to Art, it will likewise produce a great deal of Earth of the same nature with that which was procured from the original Salt. The acid Liquor, too, thus drawn from the Salt by distillation, being again distilled in a clean Vessel, will leave some yellow *faeces* at the bottom, which when they are dried, are found likewise to contain something of Earth. And these acid Salts, now, thus prepared, are so volatile, when they are accurately freed from all their Earth, that being impatient of rest, they are continually dispersed into volatile Fumes, which can scarcely be contained within their Vessels, and fly off as soon as ever they come to have a free communication with the Air; as appears evidently in the distillation of *Aqua Fortis*, Spirit of Nitre, *Glauber's* Spirit of Salt, and Spirit of Sea-Salt; for in these the pure Volatile acid Salt spontaneously resolves itself into white or red Fumes, and without the assistance of any external cause, immediately flies off into the Air. If you thoroughly now consider these *Phænomena*, perhaps you will think it not very absurd to suppose, that all these acid Salts hitherto described, would not of themselves be at rest in our Air, but that they owe this rest, or as the Artists call it, fixity, principally to the latent elementary Earth, which secretly uniting with them, fixes their volatility, and thus holds them down: And on the other hand, that whenever they are disengaged from their confinement, and get free, they then spontaneously regain their former and proper volatility. Supposing, therefore, this

this to be the case, then both the simple Acid, and alkaline Salts, would, as has appeared by the former Experiments, from the purity of their simplicity, be always volatile, and then only become fixed when they were intimately united with Earth. In this Doctrine, however, there are two things that ought to be taken notice of; first, that the Acid of Vitriol, and burnt Sulphur, remains fixed in a Fire of 560 degrees, tho' it is purified by repeated distillation, and has deposited its *fæces* at the bottom of the Vessel. This, I confess, indeed, may possibly be owing to some non-acid that is intimately mix'd with it, whether you suppose it of a metalline or terrestrial Nature, that cannot easily be separated from it; for during the distillation, the Receiver is filled with very volatile Fumes, which, if there unfortunately happens to be any crack through which they can make their way, burst out in a deadly Vapour: Secondly, that the most volatile acid Salts, by being united with a very volatile alkaline one, are converted, without the assistance of any Earth to fix them, into a compound *Sal-Ammoniac*, which is semi-fixed. But to proceed, if Fossil Alum is dissolved, chrystallized, and treated in the same manner as the Salts abovementioned, from this likewise may be procured a great quantity of Earth, which being perfectly separated, this Salt too becomes volatile. This likewise in distillation sends forth a very volatile and pernicious Vapour, and leaves a great deal of a kind of Lime-Earth at the bottom of the Retort. But prosecuting these inquiries still farther, I dissolved some Vitriol in Water, and digested it, and by this means procured from it a large quantity of Earth, called Ochre: And whilst I patiently repeated the former work of solution, and chrystallization, and in the same manner removed the *fæces*, all the Vitriol was converted into a yellowish *Calx*, which was the greatest part of it, a volatile part that was dissipated into the Air, and a thick Liquid, which was pinguious, and very austere. These *Fæces*, now, I am very well apprized, indeed, cannot properly be referred to elementary Earth, but are rather the *Calx* of the corroded Iron: In the other particulars, however, this *Analysis* of Vitriol resembles the former Operations. The *Calx* now thus procured, may, by a very strong Fire, be converted either into Copper or Iron, according to the different sort of Vitriol you make use of; and hence we evidently see what judgment we ought to make of that opinion, which some Persons have fallen into, who upon seeing the separation of such a *Calx* from a metalline Vitriol, have hence inferred, that Earth itself enters into the composition of Metals. For my own part, I confess, I don't remember, that by any one Experiment I have ever discovered a true Earth in Metals: As for that which is offered for it, it is capable of being melted into Glass, and by this very property shews, that it is not of a terrestrial nature, and gives strong suspicion that it is of a metalline one.

If we examine farther, the fossil liquid Sulphurs, and the substances produced from them, as the *Asphaltus*, Bitumens, *Naptha*, *Petroleum*, and *Oleum Terræ*, these, if they are exposed to an open Fire, burn in Flames, produce Soot, emit black acid Fumes, and when they are quite consumed, have something of Earth at the bottom; and from this, if by farther burning you reduce it to a *Calx*, you will always be able to obtain a pure Earth, exceedingly like that from Animals, Vegetables, and Fossil-Salts.

And in sulphureous Liquids.

And Solids.

And as for true Sulphur, if you sublime it into flowers in a close Vessel, it will always the first time leave some Earth at the bottom; tho' the Flowers, indeed, thus produc'd, in a second sublimation scarcely yield any. But if with the purest Sulphur, you intimately mix over the Fire an equal quantity of a very pure alkaline fixed Salt; then the compound that arises hence, being put into a clean glass Basin, and exposed to the Air in a place free from Dust, will very soon dissolve into a Liquor, to the bottom of which will subside a great deal of Earth. This Earth you may possibly attribute to the Alkali; nor do I deny but this may be concerned in it. Give me leave, however, to assure you, upon undoubted evidence, that the Oil, which, in conjunction with the fossil Acid, produces Sulphur, contains likewise, and will yield a good deal of Earth. Hence, therefore, you will be apt to be of opinion with me, that this Earth may in this case be regenerated in the resolution of the Sulphur, and thus discover itself to the Operator.

Is there any
likewise in
Metals?

The most ancient of the Chemists who got a knowledge of the Laws of Nature purely by the assistance of Experiments, were of opinion, that all Metals consist of Mercury exceedingly homogeneous, and another principle, which gives it fixity and ductility under the Hammer: That these two Principles alone enter into the composition of Gold and Silver; but that in the other Metals, besides these two, there is likewise another matter that won't bear the Fire, is subpinguious, and in some measure inflammable, which being intimately mixed with them in their original formation, becomes very firmly concentered with them: As for any other Principles, they scarcely make mention of them in their natural History of Metals. The Moderns, however, relying upon the evidence of their Experiments, every where in the *Analysis*, and composition of Metals, tell us of an Earth, and that too, one that will vitrify, which enters into their composition, and is the firm *Basis* of them all: But this Earth, which they thus tell us may be procured from Metals, does not, in reality, answer to the character of Earth, and therefore in a strict sense does not deserve the name of it. For my part, I have taken a great deal of pains in that affair, but have never yet, I confess, been able to discover in them any true Earth.

Scarcely in
Mercury.

Mercury, when it is fresh brought out of the Mines, if it is strongly pressed through a thick Leather, seems to leave a little Earth behind it, whilst it thus passes through its Pores. If you then, after it is depurated in this manner, distill it in a clean glass Vessel, it will leave a small quantity of *Fæces*, of no weight hardly, or scarce worth taking notice of. Nor can I, indeed, venture to call this, Earth, which is thus separated from the Mercury by distillation, since the distinguishing marks, by which we before defined Earth, are not found to belong to these *Fæces*. Take then this Mercury, now rendered exceeding pure by distillation, and put it into a strong glass Bottle, made of deep green Glass, and so thick, that it may bear the concussion of the Mercury without any danger of being broke: Then stop the mouth of the Bottle exceeding close with a Cork covered with a Hog's-bladder, which drive in tight, and then secure it all round with Pitch, that let the agitation be ever so great, none of the Mercury may be able to escape out of the Bottle. This being done, let the Bottle with the included Mercury be mov'd very strongly about, and for a great while together; which will be best effected by fastening

tening it to the Sails of a Wind-mill, or fixing it in some swift carriage that is every day driving about: And by this means, the Mercury being thus continually agitated within this narrow compass, the greatest part of it, without the addition of any thing else, will be converted into a dry, black, heavy, fine Powder, which is exceedingly efficacious in curing stubborn Ulcers, and as it is imagined, is scarce dissoluble in any *Menstruum*. This very extraordinary Experiment, which has been tried by the egregious *Homborg*, and which few people are acquainted with, has given occasion to its being asserted, that true Earth may be produced from the very Body of the Mercury by this simple mechanic motion; whilst on the other hand, others have rather been of opinion, that the pure Mercury, by being agitated by this continued concussion, disengages itself from the terrestrial part, which nature had united with it in its formation; and that, therefore, that part of the Mercury, which remains after this separation, being purified, and freed from its unactive Earth, become agile and pure, and by this means grows fit for the profound Operations of Alchemy, and is, in reality, the so much wish'd for *Mercurius Soporatus*. Perhaps you may desire to know what is my Opinion of this Affair: In short then, I take the liberty to assert, that the Powder thus described is not elementary Earth, much less an Earth, that as a constituent Principle, enters into the composition of native Mercury. And if any Person will but take the pains to examine this Earth by calcination, and nicely observe the various and wonderful Colours that successively appear in it, and will in particular, at the same time consider its wonderful virtues in curing carcinomatous Ulcers, I am persuaded he will hardly be of opinion, that this is the mere simple Earth of Mercury. Nay, but should I assert farther, that this Powder may be dissolved in various *Menstruums*; and that afterwards it may be reduced again into pure Mercury, it would not be without foundation. Believe me, Gentlemen, who have had long experience in these things, minds that are always ready to run into hasty conclusions, are not properly suited to the prosecution of the chemical Art, which discloses its secrets to those only who are patient of labour, and carefully compare together the events of various Experiments, whom it rewards with proper discoveries. As it is exceeding difficult, therefore, truly to demonstrate any Earth in Mercury, so on the other hand it is easy enough to come at the knowledge of many various forms of this changeable Body, which from its own nature is capable of being converted into a thousand odd and different appearances, and thus imposes upon the unwary, tho' at the same time it remains always one and the same at the bottom.

And let a Man, now, examine the rest of the Metals ever so accurately, where will he be able to discover any Earth in them? In the *Calx* of them? These certainly all continue true Metals: For altho' the *Calx* be insipid, inodorous, fine, and sometimes too pulverizable, yet, by the addition of some reducing Powders, as they call them, and other contrivances, they may be brought back again to their original form. Whoever, therefore, looks upon these *Calx's* as true elementary Earth, may suppose with equal reason, that by these slight methods, too, he is able to transmute Earth into Metals whenever he pleases. But besides, the Metals calcined in this manner, may, by the efficacy of the Fire alone, or by admixture of some other substances with them, be converted into true Glass, which every one, who is acquainted with these things, knows

Not from
other Me-
tals.

knows very well, can scarcely be affirmed of pure simple Earth. In the mean time, however, I must caution you, that the baser Metals, Iron in particular, when they are analyz'd according to Art, do yield something that comes very near to the nature of Earth; tho' this, indeed, is but in small quantity, and even here does not appear to be perfect Earth. But whilst we are upon this head, give me leave to lay before you, what I myself, after a great deal of pains in examination of Metals, have been able, with certainty, to discover. If Gold, Silver, Copper, Tin, and Lead, are first prepared in a certain simple manner, and then accurately mixed with the purest Mercury, and by this means intimately dissolved, and are afterwards digested for a long space of time, and then either very patiently rubb'd or shook about, there will at last be produced from this Mixture, a great deal of insipid, inodorous, fine black Powder, which in all of them, will be of the same kind, and which being perfectly separated by Water and Motion, will leave a pure metallic Mass. This being agitated by farther shaking, or rubbing, will generate as before a large quantity of the like Powder; and this will be always the event, tho' this Operation should tediously be continued for years together, as I myself have often experienced. If those Gentlemen, therefore, who in their Writings suppose Earth to enter into the composition of Metals, had prosecuted these inquiries in the same manner, they would not certainly, in order to confirm their opinion, have too hastily referr'd us to this Powder. For my part, who have hitherto laboured in vain to bring these Experiments to the desired issue, I am obliged ingenuously to confess, that the Powder procured by this Art, is by no means Earth, but a wonderful metalline Production, whose properties I have found to be very surprizing. Upon this head, therefore, I may be excused at present saying any thing farther, as I think, to the wise, what I have offered is sufficient. If any Person goes about to seek for a true Earth in this metalline Powder, he will hardly accomplish his end; tho', at the same time, he will discover a great many things that he never dreamt of. And, indeed, upon the evidence of what I have seen, whilst I have been closely engag'd in these pursuits, I may almost venture to affirm, that neither Gold, Silver, or Mercury, contain any thing of Earth in their natural Composition; but that they are formed of such a nature, that tho' they are divided into their least possible parts, yet they will still retain such a disposition, as will render them fusible in the Fire, or ductile under the Hammer. Concerning Gold, I can testify myself, that I have reduced it into a Liquor by the assistance of fossil Acids, I have formed it into soft Pastes, and procured *Calx's* from it in different manners; it may easily, likewise, be converted in a volatile scarlet Oil; it may be chang'd into a Substance like Butter; it may be turned into Glass; and it will sometimes most exactly resemble Earth: But still, notwithstanding its appearing under all these different forms, it may always be again reduced to Gold, perfectly the same in all respects, its weight not in the least, either increased or diminished. And after an incredible number of distillations of it with Mercury, I have always at last procured my Gold again. With Silver too, I have performed the same tedious Operations, and the event has been constantly the same. Upon the evidence, therefore, of these Observations, I could not help again admiring the ancient Alchemists, who have openly told us, that Gold and Silver are generated from pure Mercury alone,

fixed by a condensing Sulphur; and that the rest of the Metals too, owe their origin to the various combinations of a Mercury less pure, and a Sulphur less defæcated.

From the Doctrine, now, that we have thus delivered, we may deduce the following Corollaries. Hence then it appears in the first place, that the very same simple elementary Earth, concurs, as a constituent Principle in the formation of the particular corporeal fabrick of Animals, Vegetables, and some Fossils, that are less durable, and less simple: That in all these it serves as a firm *Basis* to give them their proper form, and unites all the other Principles, both with itself, and with one another, into one single particular Body: That by this means, it fixes, retains, and keeps from dissipation the other parts, that are of themselves too volatile, and thus disposes and qualifies every Body to continue what it is for some time, and that, both with regard to the whole Body, and every part of it: That this is the principal natural cause, that the whole frame is not too easily, or too quickly dissolved, either by the Air, Water, its own proper juices, or even Fire itself: And that to the efficacious concurrence of the Earth, therefore, in giving to every single Body its proper and peculiar structure, must be ascribed in an especial manner, the power of assimilating foreign substances into the nature of the Body that is nourished, and consequently, in some measure, the seminal vertue that Bodies have of generating their like; for this always perishes in every particular Body, as soon as ever its structure, which depends principally upon the Earth, is destroyed. 2. These Bodies, therefore, that owe their origin to the very same Earth, must in this respect, wonderfully agree with one another. Nor, indeed, do they resemble one another only in respect of their Earth, but generally likewise, in the very great affinity there is between their other concurring Principles. If you consider all the different kinds of Animals, in what a vast number of circumstances are they like one another? As Vegetables, we see all agree in many surprizing Properties. The Elements of Animals, we observe, are continually changing into the Matter of Vegetables; whilst on the other hand, the Bodies of Animals are perpetually supported and nourished by the Vegetables which they take in, and assimilate to their nature, and which afterwards actually enter their very make. The same thing likewise holds true in most kind of Salts, which are partly composed too of this Earth. Who will pretend to assert, that Salt of Nitre, or Sea-Salt, are so very remote from the disposition of the animal Body? But in these we discover the same Earth. And hence, by the way, it comes to pass, that alcalious fixed Salts, when they are taken in a moderate dose, are so easily assimilated to the animal Nature: For if a strong healthy Man takes small quantities of these, at suitable distances of time, they will lose their proper qualities in his Body, nor will there any fixed Salt appear in his Urine. 3. Bodies, therefore, that owe their origin to the same Earth, are easily transmuted into one another. 4. Iron, which of all the Metals seems to come nearest to the Earth of Animals and Vegetables, must be allowed likewise to come nearest to Animals and Vegetables in nature, and seems as if it might in some measure be dissolved in them: And hence it yields a noble, and very safe remedy for Diseases of the human Body, whilst the rest of the Metals act with more violence. 5. For these, as they do not acknowledge Earth, but Mercury for their *Basis*, seem to remain
immutable

immutable in all Bodies, nor appear to be capable of being digested by our concoctive faculties. For this reason, therefore, they always continue foreign to our nature, and contrary to it; and tho' sometimes in certain exceeding stubborn diseases they are of service, yet if you regard them in another view, they seem intirely superiour to the animal powers. 6. If there was no such thing, therefore, as Earth or Mercury, would all the Bodies that we are acquainted with be active, volatile, and so subtil as not to fall under the cognizance of our senses, and consequently be floating Atoms? Even the Sulphur of Metals itself, before it fixes, and is fixed by Mercury, the Alchemists tell us, is of all Bodies the most subtil and volatile. Concerning the rest, the doctrine we have above delivered leaves us no room to doubt. 7. Earth, therefore, principally furnishes the Chemists with their Instruments and Vessels. All kind of Glass has a great quantity of terrestrial matter united with its fixed alkaline Salt; and therefore, in this respect, owes its origin to Earth. As for the Potter's Vessels, these consist chiefly of pure Earth, compacted into a solid Mass, by the intervention of Water. China-vessels too must be referred hither, tho' they are of a particular kind. And Chalk, on account of its great likeness, may be reduced hither also. 8. But again, pure Earth being mixed in a proper quantity with pure fixed Salt, prevents their running into a Mass, if they are exposed to a strong Fire, which would certainly have been the case, had the Earth been away. And as by this simple intermixture it thus hinders their fluxing, so likewise, at the same time, it renders them volatile, tho' they were ever so fixed. Salt of Tartar may serve as an instance of this, which, if it is very good, and has nothing else mixed with it, will melt in a strong Heat, and if it don't insinuate itself through the Pores of the Vessel, will continue fixed there a great while; and yet, if you accurately mix it with three times as much pure Earth, calcin'd Bones, for instance, and then expose it to the same Fire, it will in a short time almost totally fly off, nor will it run as before. In the same manner, Nitre and Sea Salt, more particularly, if they are alone, and urged with a strong Fire, will flux, and remain fixed; if you mix Earth with them, they will not melt, but will be converted into Acids, and become volatile. Pure Earth is, likewise, of excellent service to the Chemists, when they want to purify animal or vegetable Salts from the Oil which tenaciously adheres to them, and renders them very impure; for when these are exceeding foul from the empyreumatical Oil that is united with them, by the mixture of very pure Earth, they will be disposed to rise in a proper Heat of an exceeding white colour, depositing all their Oil in the bibulous Earth, and being by this means intirely freed from it, which, without the addition of such Earth, would be very difficult to accomplish. And here the purer and dryer your Earth is, and the greater quantity you make use of for this purpose, the finer and more perfect will you obtain your Salt, especially, if you make use of a tall Vessel, and expose it but to a gentle Heat: With these circumstances the operation is always performed most to advantage, which was formerly very cautiously concealed among the *Arcana*. 10. This same Earth, again, by being mixed with a great many Substances disposes them to discharge a flatulent Vapour, which otherwise, upon the application of Fire to them, would make them puff up to such a degree, that not being able to bear the Heat necessary for the distillation, they would swell and

and rise in the Retort in such a manner as to run over into the Receiver, and thus confound every thing together, and prevent the hop'd for effects of the operation. If a person has a mind to distill Honey, for instance, or Wax, for any valuable purposes, he will lose his labour, if he makes use of these for this operation by themselves: For by a gentle Heat you won't be able to bring about the separation of these tenacious particles; and if you apply a strong one, these Substances will swell and puff up, like a sponge, and by this means, in a liquid form will rise through the neck of the Retort, altered, indeed, but not separated, according to art: But when by practice the Operator has learn'd to mix a proper proportion of Earth with them, then the effect of the tenacity of the Particles being prevented by the interposition of the Earth, they will bear a considerable Fire, without any danger of this inconvenience, and the flatulent expansion being thus restrained, the separation of the parts by the action of the Fire will be equable and regular. Nor is this observed to be the case only in such kind of viscid Bodies, but it is found to hold true, likewise, in others. Take, for instance, Blood, Eggs, or Urine, and by very patiently and cautiously distilling them, proceed till you have drawn off all the volatile parts, and there remains a fixed Substance at the bottom of the Retort: If then you increase your Fire to the last degree, the whole Mass being now grown tenacious, like pitch, will be wonderfully expanded, will cohere together, and in this manner will rise into the narrow part of the neck of the Retort, will fill and stop it up, and thus inclosing the Matter, which is under it, and which too is equally expanded, has been often the occasion of the Vessel's being burst in ten thousand pieces, in a very dangerous, and sometimes fatal manner. All this violent effect, now, may be prevented, by throwing only a terrestrial Powder upon the Matter that you are about to urge in this manner; and hence the addition of Earth is of vast service in the production of Phosphorus from inspissated Urine, by the extreme force of the Fire. 11. All that I have hitherto laid down concerning the nature of elementary Earth, must by no means be applied to our common Sand, which many persons very wrongly imagine to be true Earth: For this, if it is very pure, upon examination with a microscope, discovers itself to be nothing but a heap of small, pellucid, multangular chrystals, every one of which is of a different size and figure: These, in conjunction with a fix'd Alkali, will easily run into Glass, as has long ago been discovered: These the wise Author of Nature has disposed about the World, that the fructifying Water might be always able to insinuate itself through the pores of the Earth, which would otherwise very easily unite and coalesce into one Mass, and by this means in a short time acquire a perfect stony hardness, to the infinite detriment of Mankind. Nor must we refer the Boles, or medicated Earths, commonly called the scal'd Earths, to this natural class of elementary Earth: For who don't know, that these are compound Bodies? That somewhat pinguious predominates in them, the Writers of Natural History have long ago taken notice; and hence they have called some of them, the *Axungia* of the Earth: In others of them there is somewhat of a saline astringency, sometimes of the aluminous, or vitriolick kind, to which their particular virtues are owing; not to mention any more of them. When Water, however, and Fire have exerted their utmost force upon these Boles, then, I confess,

fects, they come nearer to true Earth, but then too they lose at the same time their medicinal virtues. But least of all, must we, in a chemical sense, look upon the earth, as it is commonly called, which we tread upon, and which furnishes us with supplies both of health and life, as such an Earth as we have been describing. For this our Earth evidently contains fat Clays, medicated Boles, sterile Sands, little Stones, Water, Air, Oils, Salts, all the Elements of Animals resolved into their Principles, and all the Principles of dissolved Vegetables, blended, and confounded together. This, therefore, appears to be so far from a pure Element, that if we would consider it in a proper view, we must regard it as a Chaos of all the natural Elements, and the Bodies compounded of them. Many things more, Gentlemen, I could offer upon this Head, but by the length of my discourse, I am sensible I have already grown tedious. What things I have delivered, however, I think I could not length omit, as they are every where of service, nay, indeed, and necessary to be rightly understood. You'll be so good, therefore, to excuse my entering so minutely into these inquiries, if it was for no other reason than this, that you have by this means had a faithful account, at least, if not a compleat one, of those four Elements, by the concurrence of which the most ancient of the Philosophers supposed every kind of Bodies to be formed. The particular opinion too of the Alchemists, upon these subjects, you have here had likewise laid before you. And lastly, I may almost venture to doubt, whether you have not here met with some things which were never published before. You have seen, that what are generally looked upon as Elements, are, in reality, mixed with an incredible quantity of various Bodies, and by this means are of an exceeding compound nature: That these, however, when they are artfully separated from every thing else, and thus obtained perfectly pure, and by themselves, far excel all other Bodies in their individual simplicity. What is there in Nature more simple than pure Fire, Air, Water and Earth? And again, in another sense, what is there that is more compounded? I have endeavoured to offer nothing concerning these Elements that is not sound, and will bear the test; and therefore always caution'd you where I was at a loss myself, nor have ever been too hasty to come to conclusions, where the thing was doubtful. What I have interspersed concerning Metals, I formerly did not think to have added; but the diligent attendance with which you have honoured me has drawn it from me.

Of CHEMICAL MENSTRUUMS.

Having thus, Gentlemen, dispatched those four Instruments both of Nature and Art, Fire, Air, Water, and Earth, let us now pass on to a fifth kind, which is look'd upon as almost proper to Chemistry, and to which the Masters of this Art assign the principal place, valuing themselves particularly upon it, and chiefly ascribing to it the surprizing effects of their Art; and this they have called a *Menstruum*.

Definition
of a Men-
struum.

By this barbarous term, now, they designed to express a Body, which being applied to another, according to the rules of art, would so minutely divide it, that the Particles of the Solvent should be perfectly intermixed with those of the Solvend, or Body to be dissolved. This definition I chuse particularly for this reason, because it accurately distinguishes the action of a *Menstruum*.

struum from the other solutions of Bodies, which are performed chiefly by the mechanical powers: For in these cases, the Solvent recedes from the Solvend, nor is reciprocally dissolved by it, but as soon as ever the solution is over, they separate from one another, according to the disposition of their specific gravities.

The reason of a Solvent's obtaining this name, was this; as the application of the *Menstruum* to its Solvend was promoted particularly by the help of a moderate Fire, which was constantly kept up for forty days, or a philosophical month, hence the Solvent came to be called the Solvent *Menstruum*, and at last by the simple name *Menstruum*. The reason of the term.

From the nature of a *Menstruum*, then, it will follow, that this itself must be equally dissolved by the Solvend, as the Solvend is divided into its parts by the *Menstruum*. And this circumstance obtains in every kind of solution whatsoever, that is effected by the help of a *Menstruum*, though, at the same time, it is true, it may happen, that when the Solution is perfectly compleated, the Solvent and Solvend may be separated from one another. And, indeed, in the Solutions that are performed by the Liquor, Alcahest, *Van Helmont* tells us, the Solvent and Solvend are distinguished into two different *Strata*, lying upon one another; but setting aside this, this separation is rarely observed in these solutions. The proper faculty, therefore, of the Solvent consists in this, that it on every side applies its own particles to those of the Body to be dissolved. The divided Particles, therefore, of the Solvent must insinuate themselves between those of the Solvend, and so interpose themselves between their Surfaces, and thus divide the Body to be dissolved. And at the same time that this happens, you see, likewise, that the *Menstruum* must be separated into its minutest parts by the divided Particles of the Solvend, as well as that is separated into its Particles by the *Menstruum*. And hence, likewise, appears the truth of our former assertion, that this action of a *Menstruum* is absolutely different from any common mechanical separation; for in this case, the dividing Body remains whole and intire, both whilst the division is effecting, and when it is compleated. This you see evidently in the action of a Knife, Wedge, Sword, Ax, Hatchet, Saw, Dagger, Augre, and Hanger; for these all, whilst they divide, are not divided, but remain nearly the same they were before. In the mean time, however, if we examine into this Affair more nicely, there will be room to doubt, whether every single Particle of the *Menstruum*, separately considered, does not, whilst it is dissolving, act in reality, in the same manner as the Instruments just mentioned. Certainly, one such dissolving Element will have its proper size, figure, hardness, and weight, and will act by these Powers, which so far may be called mechanical. At the same time too it is constantly true, that every *Menstruum*, whilst it is dissolving, and even in this respect, that it does dissolve, as it is then divided into Particles that, on account of their subtilty, become insensible, must for this very reason be a Fluid, and in the very point of time that the Solution is perfected, the Solvend too itself, as such, must likewise be dissolved into a fluid Body. Hence therefore, at last, it follows, that at the time of solution, the Solvent with its Solvend will be converted into one Fluid. Property of a *Menstruum*.

But here it is necessary we take notice, that many *Menstruums*, before they perform their office of dissolving Bodies, are themselves solid, hard and dense; Division of *Menstruums*.

though indeed so long as they continue in this solid form, they by no means act as such. By use, however, it has obtained, that these should be called *Menstruums*. And hence the Chemists have always laid down, that some *Menstruums* are hard or solid; others fluid. And this division may be allowed of, if the distinction just mentioned is first properly understood.

1. Into those
that are dry
before the so-
lution.

To the hard, dry, and solid *Menstruums* then may be referr'd the following Bodies, which we have reduced into their proper classes. 1. The fix solid Metals, Gold, Lead, Silver, Copper, Iron, Tin. These, now, when they are cold, hard, and solid, have no effect at all upon one another, but when they are put in fusion, may be so intimately mixed together, that to the senses the Mass will appear homogeneous, nay, and will have this surprizing property, that in every single Particle of the compound, there will be found the very same proportion of the different Metals, as there is in the whole Mass. For if in a strong Fire you melt ten ounces of Silver with one ounce of Gold, and thus form a Body of eleven ounces; then if you give but one grain of this mixture to a person well skill'd in the docimastic art, he will return you $\frac{1}{11}$ of a grain of Gold, and $\frac{10}{11}$ of Silver. But another thing here still more remarkable is this, that it is possible to divide Gold in this manner as long as ever you please, without any limitation hitherto observed; for if with a hundred thousand parts of Silver I thus mix one part of Gold in the Fire, and then examine but one small Particle of this whole Mass, according to the rules of the metallurgic art, the event will be exactly the same as the former. This surprizing *Phænomenon* then evidently demonstrates the very extraordinary power that Metals have of dividing one another by the sole help of fusion. Consider, I beseech you, to what an expansion this small Particle of Gold must be distended in so great a Mass, to effect, that there shall not be the least Particle of Silver assignable in the whole, in which there will not be always a proportionable part of Gold; which nevertheless continues still immutable among other immutable Particles, exceeding dense among other dense ones, and perfectly simple among other simple ones. Think of these things, Gentlemen, attentively, for it is well worth your while, and learn hence how wonderfully the Great Creator has formed these Metals: Certainly you will discover here somewhat infinitely mysterious, and that surpasses all human comprehension. Upon the contemplation, possibly, of this property, the Chemists have so often asserted, that Metals are opened by Metals alone; that nothing is intimately admitted, or enters into Metals, but Metals themselves; and that the Mercury of Metals is of infinite subtilty, and continues always the same. 2. Solid semi-metals, to which may be referr'd Antimony, Cinnabar, Bismuth, Mercurius, Zincq. These too, like Metals, when they are melted in the Fire, may be mixed together, and will divide one another no body can tell how far; and these, likewise, may be mixed and blended with Metals with the same success: Cinnabar, indeed, with more difficulty; the rest easy enough. But with this admixture with Metals, they constantly destroy their malleability, and render them so brittle, that they will suffer themselves to be reduced to powder, though before they were ever so tough: And this again holds true in every the least Particle of the Metal. Here, therefore, likewise you have a wonderful *Phænomenon* that deserves your consideration. 3. To dry *Menstruums* again must be referred all perfectly dry Salts, Alum, Borax, Nitre, *Sal-Ammoniac*, Fountain Salt, *Sal-Gem*, Sea Salt, Vitriols,

Vitriols, dry, fixed alcalious Salts, and corrosive Sublimate of Mercury. All these, now, when they are acted upon by the Fire, or melted, bring about by their dissolving powers, very extraordinary effects, scarcely imitable in any other manner; and they suffer themselves, likewise, to be very minutely divided by the Fire, and by this means may be intimately mixed, not only with one another, but also with Metals, Semi-metals, and other Bodies. 4. Among these must be reckoned all hard, fossil Sulphurs, quick Sulphur itself, common Sulphur, Arsenic, Orpiment, and Cobalt. In these, likewise, when they are assisted by the Fire, or melted, and so mixed with one another, or other Bodies, there is a wonderful dissolving power, by which they produce such effects, as we can scarcely accomplish by any other causes. 5. And lastly, under this head I reduce all those kinds of Fossils, which the Metallurgists commonly call Cements; for these consist of Salts, Sulphurs, and Bricks, reduced to a dry powder, which is then disposed between plates of Metals, either to heighten their colour, or to separate them from one another.

But among the various *Menstruums*, we find some, likewise, that, after they have performed their solution, and are left to themselves, coalesce into one hard Mass, which to our senses appears simple, and every where of one uniform nature. And the apparent simplicity is here often so great, that though the Mass is compounded in this manner of different Substances, yet still it appears simple. To Lead, whilst it is in fusion in the Fire, pour melted Tin, and they will run and mix together, like Water with Water, or Mercury with Mercury; and this will always be the case, let the proportion of one to the other be what it will. Look at these Metals thus melted in the Test, and you won't discover the least sign of any different Substance; and if you suffer them to grow cold together, they will form one solid homogeneous Mass, that appears simple to the sight, and will afterwards continue so. The same holds true in all Metals, and in some Semi-metals beforementioned. If to a pound of melted Tin, in the Fire, you add a scruple of *Regulus* of Antimony, when the Mass is cold, it will appear homogeneous, and be so brittle through the whole, that take ever so small a particle of it you will not find the malleability in it that is natural to Tin; but on the contrary, you will always find a proportionable part of the Antimony mixed with it. Does not a fixed Alkali run, likewise, with Sand or Flints into one simple Mass? But there are an infinite number of like instances, as you yourselves very well know, and therefore these we have mentioned are sufficient. In all these cases, now, the Particles both of the Solvent and Solvend are so minutely divided, intermixed, and concreted together, that they form a new Body, in which it is not possible for any person that don't know the composition to discover the concurring Substances, except by some other contrivance he again resolves the Body into its component parts. Sulphur too and Mercury are by rubbing converted into a black, dry powder, and this being sublimed with a strong Fire, produces a Cinnabar, of a beautiful red colour, and to all appearance, exceeding simple. But in the second place, it is likewise observed, that a great many solvent Fluids perfectly dissolve solid Bodies into their ultimate parts, but when the solution is completed, unite again in one hard, and often dry Mass. Not to mention again Sulphur and Mercury; if we examine almost all the *Menstruums* of Metals, don't we find, that these

2. Into dry
ones after so-
lution.

unite

unite with their Metals into Vitriolick Masses that are considerably firm, and durable? The very strong Acid of Wine, Vinegar, after it has corroded Oyfter-shells, Stones, or Chalk, separates from its aqueous part, and with these dissolved Substances hardens into a dry Mass.

3. Fluids before solution.

But a great many, and perhaps the greatest number of *Menstruums*, do really exist in a liquid form, before they perform the office of solution; of which sort, indeed, are almost all what the Chemists usually call *Menstruums*. Vinegars, Water, fermented Spirits, saline, acid Spirits, alkaline and compound, alcalious Oils, as they are called, *per Deliquium*, and many other Liquids, are referred hither: And as all these appear in a fluid form, the action of them is much more evident, and easy to be understood; and that the more so, because they are continually in use in the Laboratories of the Chemists.

4. Fluids after solution.

And last of all, there are some *Menstruums*, or Solvents, which before solution are liquid, and when that is completed, still continue together with their dissolved Body, in the same form. This no where appears more evident, than in the Solution of the five Metals by simple Mercury; for when these are thoroughly mix'd together, according to art, there arises hence a soft Paste, which, by the affusion of more Mercury, you may dilute at pleasure, without any limitation: But scarcely any body has ever been able to render this Substance hard by the chemical contrivances that are vulgarly known. Whoever can make himself Master of this secret, will be a good, and perhaps a rich Operator; but whoever attempts it, will find in it plague enough. But again, any acid Liquids, when they have dissolved their proper Metals, if they are mixed with them in a large quantity, will, together with their Solvents, continue moist, nor will afterwards be dried very easily. Hence a great many persons have looked upon these dissolved Bodies, with their Solvents, as fixed, metalline Oils, and idly expected from them wonderful secrets; whereas in reality these are nothing more than a large quantity of acid Salts, collected about Metals. There are besides vast numbers of other *Menstruums*, which with the Bodies dissolved still continue in a liquid form, so that we need not detain you any longer upon this head.

The action of *Menstruums*.

From the consideration, now, of the several kinds of *Menstruums* just mentioned, we easily perceive, that many of them unite Bodies together, as well as separate them into their minutest parts. For it is a common observation, that when the Particles of some *Menstruums* have by their proper action dissolved their Solvents, they then so unite themselves to the Particles of the Body dissolved, that by this concretion they become together formed into a new compound Body, oftentimes very different in nature from the simple, dissolved one. And here it is likewise certainly true, that the Particles of the Solvent do not any longer continue in mutual contact, but are separated from one another, by means of the Particles of the dissolved Body that are now interposed between them: And again, that the Particles which before, by their union, composed the Solvent, are now kept too at a distance from each other, by the interposition of the Particles of the Solvent. From this division, separation, and concretion, therefore, of heterogeneous Particles thus brought about by the help of *Menstruums*, there arises a vast variety of new Bodies. But this now becomes particularly remarkable, when only some of the Particles of the Solvent and Solvent are united together into one Mass, whilst,
at

at the same time, others are not admitted to this new concretion, but appear in a different form.

Hence, therefore, it evidently follows, that the Particles of the *Menstruum* Considered more nicely. apply themselves to those of the Body to be dissolved, and become chiefly united with them, at the very instant of time that the solution is effecting. Here, therefore, some certain cause is necessary to occasion the Particles of the *Menstruum*'s receding from one another, and applying themselves rather to those of the Solvend, than remaining in the situation they were in before. And when the Particles of the Body dissolved are by the power of the *Menstruum* separated from one another, is there not a similar cause requisite, that these Particles should continue united with those of the *Menstruum*, and not rather, that after the solution is compleated, the Particles of both of them should, by an affinity of nature, collect themselves into homogeneous Bodies? This, Gentlemen, I would desire you to take particular notice of; for it highly deserves your observation.

But again, please to consider, that this cause, be it what it will, must for the very same reason be sought for in the Solvent, as in the Solvend: And hence it will be common and reciprocal in both. For when Gold is dissolved in three times its weight of *Aqua Regia* into a yellow Liquor, the Particles of Gold remain so united with those of the *Aqua Regia*, that, though those of the former are eighteen times heavier than the latter, yet they keep suspended in this Fluid, nor sink to the bottom. Is it not plain, therefore, that between every Particle of the Gold and *Aqua Regia* there is some reciprocal vertue, by which they attract, and come into a close union with one another? If this was not the case, the Particles of the dissolved Gold would certainly subside to the bottom; the saline parts in a different *Stratum* would lie next above them; whilst the Water would swim separately and distinctly at top; whereas, on the contrary, we see that all these three, though so very different in their natures, appear in the form of one simple, uniform Liquor. Both in the Solvent and Solvend.

If we may be allowed, therefore, to reason from analogy, the action of dissolving, so far as we are hitherto acquainted with it, seems rather to be performed by a certain power, by which the Particles of the *Menstruum* endeavour to associate to themselves those of the Body to be dissolved, than by one which makes them fly from, or repel one another. Here, therefore, we are not to conceive of any mechanical actions, violent propulsions, or natural disagreement, but there seems, on the contrary, to be a sociable attraction and tendency towards an intimate union. This I confess, indeed, appears a paradox: But consider, if you please, what you yourselves have observed in any violent solution; certainly, the agitation, noise, and confusion continue no longer than till all the Particles of the Solvent have united themselves with all those of the Solvend, and the very moment that this is compleated, there appears among them but an intire and perfect rest. As an instance of this, please to take notice of this Vessel, which contains some diluted Spirit of Nitre. The Liquor, you perceive, at present does not discover the least sign of motion. In this now I immerse this piece of Iron, and what a multitude of Bubbles are by this means produced spreading themselves even to the brims of this large Vessel? What a violent agitation, ebullition, noise, and almost fiery Smoak! But how long do all these last? Certainly no longer than whilst there are still left some saline Particles of the Nitre, which are not come into contact with those of the Iron, for as soon as ever this adunation is totally More from attraction than repulsion.

tally and perfectly completed, then the whole mixture is immediately quiet, and all the Acid becomes so closely united with the Iron, that it can scarcely afterwards be separated from it.

Is performed
always suc-
cessively.

Nor must we here neglect to take notice, that the whole Solvent never acts at once upon the whole Body of the Solvend; for this, as I know of, has been never known to happen: But on the contrary, the Particles of the Solvent act only upon those of the Solvend, which they first come into contact with, and having dissolved these, and separated them from the whole Mass, then other fresh Particles of the *Menstruum* apply themselves to those of the Solvend that still cohere together, and so proceed, till the solution is quite completed.

Exciting
itself.

Part of the *Menstruum*, therefore, acts upon that part of the Body which it actually dissolves and separates from it. But whilst this separation happens among these parts, from the conflict that arises between them, there necessarily follows an agitation through the whole, by which means the other Particles of the *Menstruum* which were at a distance are put in motion, and thus in their turn are brought more easily to the remaining part of the Body that is not dissolved.

And increas-
ed by Fire.

But as the agitation thus excited proves an efficacious cause in these solutions, so there is another that promotes them likewise, and that is Fire. What the consequence would be, should this be totally absent, it is not possible for any mortal to determine, as it has formerly appeared, that it is impossible intirely to exclude it from any part of space. This, however, in the mean time, we are absolutely certain of, that if Fire is applied to a *Menstruum*, it excites, supports, and increases the vigour of its action. And on the other hand, when the Fire that is every where distributed, in extreme Cold becomes less efficacious, we find that these solutions will not be effected, or at least will proceed more slowly, though they will immediately be promoted again if this is augmented.

Various in
various Bo-
dies.

But here again some *Menstruums* stand in need of a great degree of Heat, to make them capable of dissolving Bodies, as appears evidently in the solution of Metals by *Mercury*; whilst others require a very gentle one, as we see *Sal-Ammoniac*, *Sal-Gem*, and Salt of Tartar, dissolve in Water very quickly. Some again dissolve by the assistance of a moderate Heat, whereas if it is much increased, they lose this vertue, nay, and acquire a contrary power of coagulation; witness Water, which, when it is warm, will dissolve the White of an Egg, but when it boils, will coagulate it after it is dissolved.

How does
Fire assist
Menstruums?

But if we examine more nicely into the manner in which Fire thus assists *Menstruums*, we easily conceive, that it must do this, in the first place, as it puts in motion, impells, and agitates their ultimate Particles. Some farther efficacy, likewise, in this case, must be ascrib'd to its dilating the dimensions of all kind of Bodies. And lastly, as it often divides and carries off the Particles of Bodies, and thus dissolves many itself, it by this means unites its power with that of the *Menstruum*, and so operates jointly with it. In all these respects, therefore, Heat promotes the proper action of *Menstruums*, and makes them proceed more successfully, and hence, as a concurring cause, becomes necessary to them. And, indeed, in most cases, in the very act of solution, though, at first, perhaps, it is slow, the Heat successively increases, whilst the solution is effecting, which then always goes on more efficaciously, and hence

hence is commonly pretty evidently observed to have its activity more and more augmented, as the Body is dissolving. Nay, and the action of those *Menstruums* too is likewise increased by Heat, which whilst they are dissolving, produce an intense degree of Cold: This you have taken notice of in the solution of *Sal-Ammoniac* in Water, which, if the Water is warmed, will be dissolved sooner in it than if it is cold.

The changes, therefore, that are observed to be produced in Bodies by the dissolving action of *Menstruums*, seem chiefly to depend upon the very close union that arises between the ultimate Particles of the *Menstruum*, and those of the Body dissolved, and not to any real alteration induced by the *Menstruum* upon these separated Particles themselves. I am sensible, some Authors of the first rank in the Chemical Art are of a different opinion; but the thing itself, I think, favours this doctrine. For if we consider the most perfect Metals, Gold, Silver, and Mercury, when they are thoroughly corroded by their solvent Acids into a pure Liquor, how mightily altered do they appear in all their parts? and yet if they are again accurately separated from their Solvents, which may be easily effected, you may procure from them again the very same metallic Particles they were combined with, which being melted together, will give you the true Metal, without the least alteration. Hence, then, it evidently appears, that the *Menstruum* did no ways affect the intimate nature of the Particles of the Metal, but only separated them asunder, and then adhered to their external Surfaces. * This, likewise, when it is dissolved by Vinegar, or other Salts, may be again regenerated from them, without any alteration. But again, if you mix Metals with one another ever so intimately, in the Fire, and in whatever proportion you will, they will return again in the Cupel, perfectly pure and simple. I formerly distilled Gold and Silver with Mercury above fifty times, and yet when the Mercury was again separated from them, there constantly remained the very same Gold or Silver that there was in the Amalgama. Dissolve Salts, in what quantity you please, in Water, and by a proper inspissation you may procure them again, without any alteration. If by melting Salts together, you mix them ever so intimately over the Fire, by diluting them afterwards in Water, and inspissating them according to art, they will be found again perfectly the same as before. And farther, if you dissolve Salts in Oil, when they are recovered again they will be very nearly the same. Nay, even fixed Alkali's, when, with Earth that will vitrify, they are converted into Glass, may, even in this circumstance, by a chemical management, be resolved into their former Principals. Sulphurs dissolved with Salts, or united with Metals, confirm the same thing; as well as Alcohol mixed with Oils, Refins, and other Substances. These instances, then, are sufficient to evince, that the action of *Menstruums* is really the same as we have ascribed to them.

To this you will in all probability reply, that by means of these solutions, performed by *Menstruums* alone, there are very often produced new Bodies, which were never observed before. This, you'll say, is the case of Sugar of Lead, made by boiling a *Calx* of Lead with the strongest distilled Vinegar; for this will consist of the Acid of the Vinegar attracted into the Elements of the Lead, and yet if you distill this Salt of Lead in a very strong Fire, it will not yield back again a Spirit of Vinegar, but a particular Liquor that is inflammable. To this I answer: This observation is really just, and there

E e e

may

* This I don't understand, and forgot to mention to our Author. Shou'dn't it be, Lead likewise, &c.

may be brought many instances of the like nature; but then, at the same time, we must carefully consider, that the Particles of the *Menstruum*, when they once strongly adhere to the Surfaces of the dissolved Corpuscles, are not always again very easily separated from them, but are often so closely united, that they are capable of being moved about with them, and continue a long while in this union. And hence it comes to pass, that the Operator frequently imagines, that the nature of the Body is destroyed, when, in reality, the new appearance arises only from this simple conjunction of their Particles, which continue still perfectly the same. This is easily conceived of by an example. If one has a very sharp Lancet, by itself, its power of dividing appears evident to every body. If this is afterwards put into a Case, it perfectly loses, so long as it remains there, its power of hurting, though it still continues in all respects the same as it was before. Examine this Lancet again bare, and it immediately discovers its former nature. Hence, therefore, you see, the more easily the sheath comes off, the sooner will the Lancet recover its first appearance; and if it was almost inseparably fasten'd to it, every body would be ready to assert, that the Lancet was alter'd. But let us consider again a little Cylinder of choice Silver, gilt over thick with Gold, and immerfed in pure *Aqua Fortis*: In this case all the Silver will be intirely dissolved by this *Menstruum*, and there will remain in the *Aqua Fortis* a hollow Case of Gold, of a disagreeable, black colour, and perfectly intire. In the instance mentioned, therefore, it may happen, that the acid Particles of the Vinegar may be united with the Particles of the Lead, in such a manner, that they will not be separated by distillation, but will rather rise along with them. And hence any person would be deceived, who should imagine, that the Acid, by its union with the Lead, was converted into a new kind of inflammable Liquor. And, indeed, it seems exceeding probable, that this alteration that is here observed arises much more frequently from such an adunation, than from any change in the real Substance. And in separation, the same thing must be supposed to hold good; for it very often happens, that the Body to be dissolved consists of very different parts, some of which will be intirely dissolved by the *Menstruum* made use of, whilst others will not be affected by it, but will be divided from the former, and appear separately by themselves. If afterwards therefore the *Menstruum* is drawn from that part which it had dissolved, the matter that remains will be very different from what was made use of for the solution: And hence an unwary person would be ready to infer, that this Body, which he would look upon as a new one, was produced by the transmuting vertue of the *Menstruum*; whereas it had in reality effected nothing more than a mere separation of its parts.

Act solely by motion.

From all now that has been hitherto delivered upon this head, it evidently follows, that all known *Menstruums*, whilst they perform their office, act solely by motion, notwithstanding, the Chemists have supposed their action to be so abstruse and mysterious; for if a *Menstruum* did not put in motion the parts upon which it acted, then those parts would remain the very same they were before; which is contrary to the supposition.

But one that arises from a particular cause.

In the mean time, however, though this is undeniably true, yet it is not so easy to comprehend the physical cause, by which this motion is excited in the *Menstruum*. For so long as the *Menstruum* is alone, it remains perfectly at rest;

nor

nor is the Solvend in motion till it begins to be moved by the *Menstruum*; and yet as soon as ever they are brought to one another, within a certain distance, and in a determin'd degree of Heat, there arises a new, and frequently a very great motion, which was in neither of them before, but is now in both of them. Upon a careful consideration, now, of this matter, we cannot safely attribute this effect to any of the common origins of motion. In Propulsion, Gravitation, Elasticity, Magnetism, or any other general cause, if there is any other, we shall in vain seek for the Principal of this Agitation; for this is peculiar to the Solvent and Solvend, and not common to Bodies in general. Each of these, however, deserve a particular and accurate Examination; as a person who is thoroughly acquainted with the powers of *Menstruums*, will understand the principal part of the Chemical Art, and be capable of performing its most beautiful Operations. And, indeed, whilst we are upon this head, this task is absolutely necessary, on account of the authority of some very great Men, who are of opinion, that the actions of all Bodies whatsoever may, and ought to be explain'd solely by mechanical Laws. Let us therefore examine the matter fairly, and see what will be the issue.

First, then, I say, that whenever any solvent *Menstruum* dissolves its Solvend by what the Mathematicians call a pure mechanical motion, then the Particles of that Solvent must be agitated by some cause, which, though they were at rest before, will put them in motion; and this cause, for the most part, is Fire. The Particles, then, of the *Menstruum*, being thus moved by this cause, must strike upon the Corpuscles of the Solvend, which as yet cohere together, must impress their motion upon them, and by this means abrade and separate them from the solid Body, and that, either by exerting this effect upon the external Surface of the whole Body, or by insinuating themselves within its pores, and acting there, likewise, in the same manner. This, now, I am of opinion, every body will agree can be in this case the only mechanical manner of acting; which, as I will allow to have some effect, so, at the same time, I think it necessary to caution you, that it is a great deal less than persons generally imagine. Fluid Bodies, indeed, surround, press, and penetrate the Substances that are immersed in them; but then they afterwards make very little alteration in them, by their bulk, hardness, figure, and weight. I confess, indeed, that, by a motion communicated to them by the grand mover Fire, they are carried against the extreme Surfaces of the Solvends; but how little efficacious must this power be, which acts equally both upon the Fluid, and upon the hard Body, and therefore cannot exert an applying and impressing force upon it: These, certainly, must be sought for somewhere else. Can you imagine, that a mechanical Instrument, a Wedge, for instance, suppose it ever so perfect, could ever divide a piece of Wood, only by being placed close to it, or by swimming gently about it? Certainly, there is here something more necessary: It must first be fixed fast into the Body to be divided, and then, by an external force, it must be struck and driven forwards, and that without its being able to slip out whilst it is thus in motion. Try, now, if you can find all these requisites in particles quietly disposed, and freely swimming about in a soft Fluid, and wanting intirely a propelling power. But we'll suppose, for once, both the parts of the Solvent, and those of the Solvend, to be divided by a mere mechanical force, and that they are now just swimming among

Not mechanically, except rarely. Such a Solution more nicely examined.

one another; then, certainly, if there was not at the same time some other power likewise, the very moment they are thus separated, and become fluid, they would dispose themselves according to their specific Gravities, that is to say, the heaviest would sink to the bottom, and so the rest, in order, wou'd settle in distinct *strata*, nor would the heavy continue mixed with the light, nor the Solvent with the Body dissolved. When Metals, Stones, or other hard Bodies are worn away by the fall of Water from on high, or by the force of a rapid stream, you know very well, that the Water then acts only by a mechanical power, and is able indeed in this manner to divide the very hardest Bodies into their smallest Particles; but then the impalpable Powder thus produced does not mix with the Water, or is united with it, but sinks, and is collected at the bottom; and though it is agitated very frequently, yet as soon as ever it comes to be at rest again, it presently subsides. And the same thing you have observed, likewise, in the solution of Bodies consisting of terrestrial and oily parts, in boiling Water; for as soon as ever the heat of the Water has melted the Oil, it presently ascends and swims at top, whilst the earthy part falls to the bottom. These solutions, therefore, may so far be looked upon as mechanical. In this manner act, likewise, the Currents of Rivers, rapid Winds, the Sounds of great Cannon, and Thunder; and here always, as soon as ever the separation is made, and the concussion is over, the Solvent and Solvend recede from one another, as their gravities variously determine them. And thus in the fusing of Semi-metalline Glebes, Antimony, for instance, with Salts and Metals, the whole Mass, whilst you urge it with a violent Fire, appears in the Crucible to be intimately mixed together; and yet when you remove it from the action of the Fire, pour it into a melting Cone, and suffer it to stand quiet, the *Scorie* soon rise to the top, and form themselves into a Crust, whilst the pure metalline part by its weight subsides to the bottom. But a repulsive force also is sometimes a cause, that Bodies, which are mixed together, separate again from one another. This we see evidently in a very strong, alcalious *Lixivium* and Alcohol, and in Oil and Water; where not only their gravity, but this repulsion, likewise, makes those parts, that are of the same nature, collect themselves together. Metals too sometimes do the same, when they are in fusion; as appears very remarkably in Mr. *Homburg's* method of purifying Silver. We are persuaded, therefore, that those *Menstruums* alone act purely by a mechanical power, which after they have by a mechanical motion arising from their size, hardness, figure, weight, and impulse, divided Bodies into their small Particles, recede from these Particles, either upwards or downwards, according to the determination of their specific gravities, nor afterwards produce any considerable alteration by such division. By this mark, then, I think, one may be able to determine whether the action of any given *Menstruum* is properly mechanical; and such a Solution, if any such is observed, may by this means be easily distinguish'd from all others.

What Solution is not mechanical.

Whenever, therefore, we see any solution performed by means of a *Menstruum*, where the Particles of the Solvend, after they are separated from one another, cohere with those of the *Menstruum*, and remain equably intermixed with them, though there is a considerable difference in their comparative gravities, we then ought to conclude, that this Solution was effected partly by a universal, mechanical power, which almost always concurs, but chiefly by some other cause arising

arising from the particular relative disposition of the Solvent and Solvend to one another, by which power we suppose the Elements of one attract those of the other from their former concrete, and being combined together after the Solution is compleat, compose numberless new *Species* of Bodies.

Give me leave to explain this whole affair by one Example. If a Ball of soft Clay is thrown into Water, and this is set over the Fire, and made to boil; then the Particles of Water, being put in motion by the action of the Fire, will divide the Ball of Clay into its least Corpuscles, which will be intermixed through the whole Water so long as it is kept boiling; but as soon as ever the impelling force of the Fire ceases to act, and the Water is suffered to be at rest, and cool, then all the Clay soon subsides to the bottom. This, then, I should chuse to call a mere mechanical Solution, because the Particles of Water impell those of the Clay, by the motion they receive from the Fire, and when they are deprived of this, they continue to act no longer.

An instance
of a mecha-
nical Solu-
tion.

On the other hand, if a Ball of *Sal-Gem*, whose specific gravity is greater than that of Water, is put into 4 times its weight of boiling Water, the heat of the Water will presently dissolve it; but then, too, when the Solution is compleated, and the Water suffered to stand quiet and grow cold, all the Salt, though it is heavier, will still continue distributed through the whole bulk of Water. Hence therefore it evidently appears, that there is some quality in the Water, by which it unites itself with the Elements of the Salt in such a manner, that they are not capable of disengaging themselves by their weight, but are forced to remain suspended. Here, then, you will no doubt begin to suspect, that there are fewer *Menstruums* that perform their office, by a pure mechanical power, than persons generally imagine. In this manner, indeed, Water dissolves Ice, Water Water, Alcohol Alcohol, and other such Liquids one another. But there is observed, likewise, a great deal of difference in the cohesion of different *Menstruums* with the Elements of the Body dissolved; some of them cohering much more firmly than others: And hence the Corpuscles that are produced by *Menstruums* become very various; for among these, some are found to be so immutable, that they refuse to be resolved again into the simples from which they were compounded; whilst others very easily part again, and become what they were before the Solution. But of these there is no End.

An example
of a Solution
not purely
mechanical.

According to the distinctions, therefore, thus laid down, I could venture almost to distribute all the *Menstruums* I am acquainted with into four distinct Classes. To the first of these I wou'd reduce all those which act only by a simple mechanical power; which, therefore, may be explained, and understood by those mechanical principles which consider the powers that are common to all known Bodies in general. Of these, now, there are but few, and those generally very simple. The second Class should contain those *Menstruums*, which, though they do in some measure act by a mechanical impulse, yet, at the same time, perform their office chiefly by a power of repulsion. To the third should be referred those which act principally by a mutual attraction between the Particles of the Solvent and the Solvend; which very frequently occur, and are vastly numerous. Whilst the fourth and last should comprehend all those which operate by the concurrence of all the former together: And this will be much the greatest of all; as in almost all the actions of *Menstruums* a mechanical, repulsive,

Division of
Menstruums
from their
manner of
dissolving.

pulsive,

pulsive, and attractive power are united together. If it was possible, now, to accomplish, that *Menstruums* should be reduced into order, according to the difference of their manner of acting, and then be distributed into inferior classes, then the doctrine of Chemistry might be brought to the certainty of a Science; and consequently, it might always be foretold, what would happen in a particular Operation; and thus chemical experiments might be made vastly useful to the other branches of Natural Philosophy.

An example
of a purely
mechanical
Menstruum.

Of each of these solutions, now, I'll give you an ocular proof, that you may be the better prepared to understand what follows. For an Example, then, of a mere mechanical one, besides those mentioned above, let us take the separation of melted Silver into little Particles, when it is poured into cold Water. This the Metallurgists call Granulation, and it is performed in the following manner. I take an ounce of the best Silver, and put it into a strong, clean Crucible, and cover it so close with a clean Tile, that nothing from without can fall into it. I then heat the Crucible gradually, till it is almost red hot, and then put it into a strong Fire, which is kept blowing till the Silver is melted and runs like Water. The Silver then being thus thoroughly fus'd, holding it up pretty high, I pour it, as you see, a little at a time, into the cold Water, that is at least a foot deep in this Vessel; and at the same time you hear the Particles of the melted Silver passing through the Water, with a gentle, hissing noise, and perceive, that as soon as ever it comes to the Water, it flies asunder into little Grains, and in this form sinks to the bottom, both the Water and the Silver continuing exactly the same they were before. In this example, then, you see, that the Silver, when it comes melted from the Fire, and is thrown into cold Water, both divides the Water, and is divided by it, and that when the division is over, they recede unaltered from one another, and dispose themselves according to their respective gravities. If you have a mind to perform this operation yourselves, all the circumstances that I have mentioned must be carefully attended to, otherwise the Experiment will not succeed, as you have here observed it. The same may be performed with Gold.

An example
of a repelling
one.

If Copper, now, had been melted in the same manner, and then dropped into cold Water, as soon as ever it came to the Surface of the Water, it would have been repelled with an incredible *impetus*, and the whole substance of the Copper would have been so minutely divided, that scarce two Particles of the Metal would have remained united together. By this instance, then, it appears, that there are *Menstruums*, as in this case Water, which, by means of a repelling force, very surprizingly dissolve other Bodies, as we see here in melted Copper. And the event had been the same, if Gold or Silver had been mixed with the Copper, for if the mixture had been thus melted and thrown into Water, it would have flown about in the same manner. But here let me caution you not to venture too rashly to make this Experiment, which can't easily be performed without great danger to the Operator.

An example
of an attract-
ing one.

In the third place, now, I'll give you an example, where different Substances being brought into contact, divide one another, and then unite pretty strongly together. Into this earthen pan, then, which is not glaz'd, I have put four ounces of Flowers of Sulphur, and covered it carefully with a Tile, that when the Sulphur is melted, it may not take Fire. This, now, I set upon such a Fire, as is just sufficient to melt it, and to keep it in that condition, and no more.

more. In this Bag, which is made of very thick Cloth, and is very clean, I have put six ounces of the purest Mercury, and tied the back very fast at top; and the Mercury, you perceive, does not pass through the Bag, except it is compress'd. I now take off the Tile, and squeeze the Mercury very gently into the melted Sulphur, so that it falls into it gradually, in very small drops, and a very little at a time, and all the while this is doing, the Sulphur is kept constantly stirring with a warm *spatula*, which is continu'd till all the Mercury is perfectly mixed with the Sulphur. You perceive, now, there remains but one Mass, which is black, drawn out as it were into strings, and very brittle, and which, if it is examined with a microscope, glitters, and discovers some appearance of Mercury. Here, then, you have an instance of a fluid *Menstruum*, indeed, but a dry one, and a hard, dry, solvend Body, which, when they come to have their smallest Particles in contact with one another, attract and retain one another so strongly, that upon the application of Fire to them afterwards, they do not quit their hold, but rise united together, and are converted into a Cinnabar. The principles, now, that are here conjoined, how different were they, as to their origin, weight, kind, and volatility, and how distant from a combination with one another? And yet when they are brought thus close together, how tenaciously do they cohere together? What now were the causes that brought about this adunation? Why, first, the Fire, which melted the Sulphur into its distinct elements. Secondly, the division of the Mercury whilst it was made to pass through the Bag, as through a very fine sieve, by a very small quantity at a time. Thirdly, the continual agitation of the melted Sulphur, and the Mercury that fell into it, by which means they were accurately mixed together. But all these, now, did nothing more than barely apply the Sulphur to the Mercury; and therefore, fourthly, there is some other power in the Sulphur and Mercury, by which, when they thus touch one another in such a vast number of Surfaces, they attract each other into so strong a cohesion, that they require some great force, or some other power attracting one of them more strongly, to separate them from one another. And this reciprocal attraction acts here as the principal cause. And hence, fifthly, arises this constant combination, as the ultimate effect, which is so great, that if you sublime this composition in a close Vessel, it will not be divided into Mercury and Sulphur, but they will both ascend at once in very small particles of Cinnabar, in every one of which they are both always found to be united together. Nay, though after you have once performed this operation, you repeat it again in the same manner, you will not, even then, be able to separate them asunder, but on the contrary, will force them by this means into a more intimate union. It's true, indeed, that the Cinnabar, after it is once made, will not rise so easily as it did the first time, but will, upon every fresh attempt, grow still more and more fixed in the Fire, 'till it at last becomes of an exceeding fixed nature; but even in that case, the volatile, mercurial part will not divide from it, but will remain so entangled in the Sulphur, that it will not be able to disengage itself, though it is at last exposed to an exceeding strong Fire. It is no wonder, therefore, that some novices in the art should, upon the sight of this Experiment, be led to imagine, that they could in this manner produce even Metals themselves, by the adunation of these two Principles, Sulphur and Mercury.

Mercury, thus effected by the Fire, of which the Adepts unanimously agree, that Metals are compounded. They found, however, upon better examination, that they had only laboured in vain, the Sulphur in every operation still remaining Sulphur, and the Mercury under a proper management, still returning true Mercury; but as he says in *Sendivogius*, never wiser. The truth of this appears evident, by making use only of a very dry *Menstruum*, that will attract the Sulphur more strongly than the Mercury does. Take, for instance, 12 ounces of Cinnabar that by Sublimation is rendered exceeding fixed, reduce it into Powder in an iron Mortar, and then add to it the same quantity of Filings of soft native Iron, not Steel, which too must be fresh filed, not rusty; rub these then accurately together for a considerable time, and then, as before, sublime them in a Cucurbit with a strong Fire: And what then will be the consequence? Why the Mercury, to the quantity of six ounces, will rise pure, and fall in its original form, into the Water in the Receiver, and at the bottom of the Retort, there will remain a fixed Mass composed of Sulphur and Iron; for Iron being thus exposed to the Fire, most greedily unites itself with the Sulphur as its *Menstruum*, and repels the Mercury from its cohesion with it, which then flies off separately, and laughs at the too credulous Alchemist. The same thing may be effected by using a fixed alkaline Salt, instead of Iron; for as soon as ever the Salt comes to be melted by the Fire, it dissolves the Sulphur, unites itself intimately with it, and by this means dislodges the Mercury. Quick Lime too, will do the same. Another instance of a merely attracting *Menstruum*, we have in the following Experiment. Take 2 drachms of Flowers of Sulphur, add to them in a glass Mortar 3 drachms of Mercury, and with a glass Pestil rub them together, the longer the better; and by this means, the Mercury will gradually disappear, and become united with the Sulphur, and when they are intimately mixed together, they will produce a very black Powder, which was continually changing its appearance during the rubbing: And the blackness of this Powder will be so much the greater, as they are longer rubbed, and more closely united together. Hence, if you continue rubbing it a good while, it will at last become exceeding black and very fine, and if it is left to itself, in a short time it naturally hardens into a black Mass. This Substance, now, very intimately contains a latent Mercury, and fixes and retains it, in such a manner, that if it is taken by Animals in great quantities, it does not act with the efficacy of Mercury, which cannot be recovered from it again, except by the contrivances abovementioned: This may be sublimed too into a very red Cinnabar. This some of the avaritious Alchemists observed likewise, and rejoiced over their black Powder. They imagined it to be the head of the Crow, which the Adepts had told them appears in the beginning of the grand Operation, when the Principles, Sulphur, and Mercury, are properly united together. Thus again, you have an instance of a dry fluid *Menstruum*, and a solvent Body, divided only by a simple mechanical Attrition, and then by the power of Attraction remaining closely conjoined with one another.

An instance
of an attrac-
ting and re-
pelling *Men-
struum*.

I have here now some very good common Antimony reduced to Powder. This I put into this clean Crucible, which I cover close with a Tile, and when it is gradually heated, set it upon this Fire that on every side surrounds it. You see now, the Antimony begins to fume a little, and whilst I keep it on the

Fire 'till it melts, and runs like Water, it emits a great quantity of a whitish Smoke. The Crucible I then take off of the Fire, and let it stand quiet 'till it is perfectly cold. If you examine, now, the surface of the Antimony, which is now condensed by the Cold, it looks rough, unequal, and full of holes. I'll now break the Crucible; and you see the Mass of Antimony towards the lower part is solid, and shines with a metalline cast, whilst at top it is spongy, whitish, and yellowish, intermix'd with a lead Colour. Here, therefore, you see that the Fire, by melting the Antimony, has resolved it into its metalline, and sulphureous parts: That hence, these being set at liberty, have associated themselves together, the metalline with the metalline, and the sulphureous with the sulphureous, whilst the metalline parts have driven from them the sulphureous ones, and these have done the same by the metalline. And here, whilst this Solution was brought about by the Fire, Fusion, Attraction, Repulsion, and Gravity, all joined their concurring efficacy to produce this effect. If you imagine that this Experiment don't so properly belong to the nature of *Menstruums*, this at least you will allow me, that, by the help of it, we come to the knowledge of many things which actually happen in their operation.

But that I may still exhibit to you some farther instances of the action of *Menstruums*, and thus lead you to a proper conception of those which act by the concurrence of different causes, I here again take an ounce of Salt of Tartar, and half an ounce of Flowers of Sulphur, rubb'd very briskly in hot mortars, in a hot dry Air, and still continuing very hot, and put them into a Crucible upon the Fire, and cover them. You perceive, now, how soon they are both melted together, tho' the fix'd Salt melts with so much difficulty when it is by itself. This dissolved Matter, now, I pour out of the Crucible upon a clean Stone, and you see we have a homogeneous Mass, than which nothing melts more easily in the Air, especially, if it is reduced to Powder; for as you perceive, it immediately runs into a very red Oil. Hence then you learn, what a very strong adunation there is brought about between this dry *Menstruum*, and the dry Body of the Sulphur, which is so incapable of ever being dissolv'd by Water, and yet now by the efficacy of the *Menstruum*, melts sooner than any thing with the Water of the Air, which it seems to attract into it with a vast deal of greediness. But please to take notice of the following Experiment, which is more extraordinary, and what one would less expect. I have here four ounces of the choicest Antimony levigated to a very fine Powder, and rubb'd with 2 ounces of hot dry Salt of Tartar, in a hot dry Air, and with a hot Pestil and Mortar. This Mixture, now, I put into a Crucible, and melt with a very strong Fire 'till it is perfectly fluid, and then pour it into a melting Cone. And now it is cold, I strike it out, and you see it is become one homogeneous Mass, very equably dissolved through the whole Body, which flowed in the Fire just like Water. It is farther, as you observe, of an ash Colour, and it in some measure resembles Glass, is of a caustic taste, dissolves in the Air, and then changes its Colour to a bright red: Here then the fixed Alkali, the Sulphur of the Antimony, and its metalline part, are very minutely divided by the action of the Fire, and united into one kind of Body, which does not happen in these very often. But give me leave to add one more Example to the same purpose. I have here an ounce of the purest Silver,

ver, and three ounces of the best Copper. These I put into a Crucible, and melt in this Coal Fire, and now they are perfectly fused, pour them out into this little iron Mould, where we have a homogeneous Mass of Metal very equably mixed together, and scarcely separable again, except by the help of Lead in the Cupel. In this Operation, now, one Metal is the *Menstruum* of the other, as soon as ever they come to be both melted. And then it is plain, the Particles of each of them unite rather with those of the other Metal, than they do with one another, as betwixt all the Particles of the Silver, there is an equal distribution of Copper, and as notwithstanding their different Gravities, they don't separate from one another. Nor can this arise only from the action of the Fire, which may melt them indeed, and blend them together, but can never possibly mix them together in such an equal proportion. This operation, too, farther teaches us, that the mercurial part of the Silver unites itself so strongly with that of the Copper, that it will not afterwards part with it; for otherwise, the melted Silver would sink to the bottom of the Crucible, and the melted Copper swim at top of it, and after they came to be at rest, they would separate into two distinct *Strata*, as we see Oil of Tartar *per deliquium*, and Alcohol, when they are mixed and shook together in a Vessel, soon return into two perfectly distinct Bodies, which by no Art whatever can be mixed together. And here, which particularly deserves our consideration, both when they are in fusion in the Fire, and afterwards concentered in the Cold, they continue throughout mixed exactly in the same proportion. These Examples, then, Gentlemen, are sufficient to give you a notion of the various manners in which dry *Menstruums* act upon one another.

The causes
of Solution
concurring
in *Men-
struums*.

If you please, then, carefully to examine the instances we have given, and consider maturely what we have said, you will have an idea of the Solution of Bodies by *Menstruums*, very different from that which the Chemists and Philosophers commonly have, who by the true Principles of things, have endeavoured to explain chemical Operations. For they have always imagined here some mechanical Acrimony, corroding by a universal mechanical Power; and when they have observed that a *Menstruum* that corroded one Body, would not often corrode one that was softer, they have racked their Brains a thousand different ways, to reconcile these contrary appearances. We, investigating Nature by the help of Experiments alone, proceed in the following manner.

First Fire.

Upon the most careful examination, then, into the concurring causes of Solution in *Menstruums*, Fire first offers itself to our Observation. And this, if we consider it in all the various degrees which Experience has discovered to us, will be found to be almost a universal Solvent, inasmuch as it dissolves almost all Bodies, if it is applied to them in a proper strength. For if we proceed gradually from the warmth of a Man in health, to the utmost violence of *Tschirnhausen's Focus*, and make Experiments upon different kinds of Bodies through the whole compass, we shall scarcely find any that will not melt, or be divided into their least Particles, by one degree of Heat or another. For if some of them grow hard, as Bricks, in a certain degree of Heat, yet in a greater they will melt and vitrify, as is evident in the Furnaces made use of for fusing Metals. And tho' some few, indeed, will not be melted at all in the most intense Heat that we are at present acquainted with; who knows, if this was still farther increased, but these at last would dissolve likewise. We must
by

by all means acknowledge, therefore, that the power of Fire must always be very strictly attended to in the proper action of *Menstruums*. Without the assistance of this Element, certainly, the mercurial parts of Metals could never be so surprizingly united into one Mass.

In the second place, in order to understand the action of any *Menstruum*, we must consider likewise, whether there did not concur a strong and continued mechanical attrition; for this may often supply the place of Fire, and effect in some measure what Fire would have done, had that been present. For whilst Attrition attenuates, and divides Bodies, and reduces them into very minute particles, it gives them an opportunity of acting upon one another by these very small corpuscles, and thus mightily favours a very intimate Mixture. This appeared evident in the Grinding-Mill of *Monf. Langelot*, which is said to have ground Gold into a potable Liquor; concerning which, the celebrated Author, who has wrote a Treatise upon this subject, deserves to be consulted. And among the Observations of *Mr. Homberg*, we are told, that all Metals, Gold itself not excepted, have, by being rubb'd for a long time with pure Rain-water, been converted into a Liquid.

Next Attrition.

In the third place, it is farther to be observed, that when the Bodies to be dissolved have been melted into their ultimate Particles by the Fire, or been minutely divided by the Attrition just explained, or, in particular, have undergone the whole energy of them both together; then, if their Particles thus separated are intimately mixed together, it often happens, that a repulsive force, which was latent before, discovers itself openly to our Observation; which is amongst the greatest secrets of the Chemists. An instance will best explain what I mean. Melt some very pure Lead in an iron Ladle, and add to it three times its weight of choice Mercury, and mix them together, and you will have a Composition, or *Amalgama*, of a bright Colour, like that of the purest Silver. Keep this by you for years, and it will remain exactly the same, without any alteration. If you afterwards rub it in a glass Mortar with a glass Pestil, or in a wooden Bowl with a wooden Pestil, you'll find to your surprize, that the whole Mass will grow perfectly black; and if you then put Water upon it, and continue to rub it, and then pour off the Water, which will be black and turbid, there will again be a pure *Amalgama* left behind. This now will keep its appearance as before, and remain pure for a long time; and yet if you repeat the former Operation, it will again become black; nor will you, as I have learnt by Experience, be able to come at the end of your work so easily as some Authors promise you. Here then we see evidently, that the Mercury thus mixed with the Lead, does not at first repel this black Matter, either from the Lead or itself; but when by this mechanical Attrition, the attenuation, mixture, and application of the different Particles, become greater, and more intimate, there then arises such a power in the Mercury and Lead upon one another, that the intimate mercurial parts of both come into the closest union, and by this means repel from them, or as the old Alchemists called it, spues out the heterogeneous matter, which could not be separated from them by any other method, without a vast deal of difficulty. If this *Amalgama* now is distilled and cohobated with Mercury a great number of times, the action of the Fire will have the same effect, as the rubbing had before, and produce the same black Matter capable again of being diluted

A separation sometimes happens by means of a repulsive force excited by these two.

and separated by Water. Here again, then, evidently arises a repelling power, by the efficacy of which, this separation is obtained very easily. Whether this now can be effected in any other manner, I know not. Silence here is best: A word to the wise is sufficient.

Or by Attrition.

In the fourth place let me observe, that both the Particles of the Solvent, and the Solvend, when they are melted, or agitated by the Fire, attenuated by Attrition, and mixed together, often discover an attractive Power which before lay concealed, and by which they are then associated together in a surprizing, and frequently a very efficacious manner, whence afterwards arise great variety of new Bodies, which never appeared before, and which can scarcely be produced by any other means. The Operation just mentioned, with the *Amalgama*, may serve here too for an Example: For in this there is effected, by this attractive Power, a wonderful Adunation of the mercurial Particles of the Metals, which discovers itself to the Operator, after the repelling force has separated the heterogeneous Matter, which prevented the homogeneous Particles coming into a perfect union. This, therefore, being expelled in the manner explained, and the remaining part in both being perfectly depurated, the mercurial parts become intimately united together, and produce something one would not expect.

Hence the production of a new Body.

In the fifth place, if a *Menstruum*, after it has dissolved a Body, let the manner in which it effects this be what it will, I say, if this *Menstruum*, after the Solution is over, can be totally separated from the dissolved Matter, so that they may both again exist distinctly, then the Body dissolved appears by itself in a new form, and is for the most part converted into a *Calx*, or into some other kind of new Body.

Hence solid *Menstruums* act as Fluids.

From the whole, then, we see, that almost all *Menstruums*, whether solid or fluid, at the very time when they are in action, are reduced to the nature of Fluids, Attrition, perhaps, alone excepted, which often, without any assistance, renders Bodies fit for Solution: But even in this case, that the Solution may be compleat, the Attenuation must be so subtil, that the Bodies rubb'd, put on almost the form of Fluids.

I'll now, then, give you an Example, in which all these causes, Fire, Attrition, a repelling force, an attracting one, and a mechanical one, act together in dry *Menstruums*, and all their effects, viz. Attenuation, Concretion, Transmutation, and Separation, are produced at the same time; and in this Experiment I shall proceed in such a manner, that it may serve you as a pattern for any of the like nature. I have here, then, 16 ounces of common Antimony purified only by fusion, and then being suffered to settle as I shewed you before, which I have taken care should be pounded and rubbed in an iron Mortar, till it is reduced to a very fine Powder. This Powder, now, you know consists of a common Sulphur, intimately intermixed with another part which is called the metalline, or mercurial part of the Antimony, tho' there does not appear in it the least sign of these two different substances, even tho' you examine it with a Microscope. I take then of the purest stony concretions of Rhenish Wine, commonly called Tartar, 12 ounces, reduced likewise to a subtil white Powder; and of very pure Nitre 6 ounces, which, now it is finely powdered, you see is as white as Snow. All these Powders, then, I dry as thoroughly as possible, then mix them, and take care they are for a considerable

considerable time rubbed well together in an iron Mortar, that by this means they may be intimately intermixed with one another. The compound Powder then weighing 34 ounces, I set by for farther use. I now again take 6 ounces of Tartar, and 3 of Nitre, reduced separately as before into a fine dry Powder, and accurately mix them together, and from the acid Tartar, and salt Nitre, have a very subtil dry Powder, which still impresses upon the Tongue an acid taste. Now then please to observe. Into this Ladle, which I have placed on an open Fire where there is no Smoke, and which is now almost red hot, I throw in a little of this Powder of Tartar and Nitre, and you see the very moment that it falls into it, it puffs up, boils, throws out small sparks, bursts into a Flame, and leaves a white Mass, here and there a little greenish, which is perfectly fixed and alkaline. On this then, I throw a little more of the Powder, and the same *Phænomena* happen over again; and thus I proceed till all the Powder is used. Here then we see, that when the acid vegetable Salt, and the saline terrestrial Salt come to be exposed to the Fire, they fume, sparkle, burn, and are fixed into an acrid Alkali; and that all this is performed, almost, in a single point of time. But by an Experiment, that I shewed you before, I made it appear, that if a fixed alkaline Salt is rubb'd with Sulphur till they are intimately mix'd, they will flame instantly in the Fire, and the Sulphur being totally dissolv'd, will be converted into a new Body. Hence, then, you readily perceive, that if Tartar, Nitre, and Sulphur, mix'd in a small quantity, are thus thrown into a Vessel heated red hot, there will immediately be produced a fixed Alkali, which the Sulphur will instantly lay hold of, dissolve, and convert into a Mass of a peculiar nature. Having a right notion of this, therefore, let us now see what will become of our Powder of Antimony, Tartar, and Nitre, when that likewise is exposed to the Fire. To this purpose, I have placed a strong Crucible in the Fire, which was first gradually heated, that it might bear the sudden application of a strong Fire without cracking; and I have chosen one that will at least hold three times the quantity of the Powder to be thrown in. The Crucible, then, I thus cover with a Tile to keep the Dirt out, and increase the Fire gradually, till it is all over red hot. In the mean time too, I take care to have the Powder of Antimony, Tartar, and Nitre, made pretty hot, but cautiously, that it don't take fire. I now, then, take off the Tile, and with an iron Ladle throw in about two drachms at once of this heated Powder; and the very moment it comes to the bottom of the Crucible it bursts into flames, smokes, sparkles, flames, grows red hot, and lies quiet. I then proceed again to fling in the same quantity, which you see has the like effect, and so continue to the end, covering the Crucible every time, till the Ebullition is perfectly over. The whole Powder, then, being thus thrown in and deflagrated, I make the Fire so strong, that all the matter in the Crucible may be melted, and flow like Water; and after that by putting in a Tobacco-pipe, I have found this to be the case, I keep it some time in this degree of Heat. In the mean time, I have by me a conical brass Vessel, which I make very hot, and then rub over on the inside with a piece of Tallow Candle, so that the whole Surface may be covered with this pinguious Matter. And this I have found by Experience to be safer, than making use of Oil; because if there happens to be ever so little Water in it, it may produce a ter-

rible effect. The Matter then still continuing perfectly fluid, and the Crucible red hot, I take it out with a pair of Tongs, the Claws of which are suited to the figure of the Crucible, that there may be no danger of its slipping, and gently pour the melted Powder into the Cone, upon which you see, a Flame instantly bursts out like Lightning. This proceeds from the Tallow with which the inside was smear'd over, which now takes fire, and by its Flame prevents the melted substance's concreting with the Vessel. I now let it stand till it is cold, and then turning up the Cone, and striking it, the whole Mass is discharged, as you see, into this Bowl, and is now divided into two parts that are perfectly distinct: The upper part of which, or that towards the Base of the Cone, is of a dark brown colour, weighs 14 ounces, and is what the Workmen call the *Scoriae*: These are brittle, of a caustic taste, and brown colour, melt in the Air, and then become red, and consist of a fix'd alkaline Salt produc'd from the melted Tartar and Nitre, and the Sulphur of the Antimony, reduced by the Fire with that Alkali into one Body; which afterwards being fused with an intense Heat, was repelled by the other metalline part of the Antimony, and rose to the top, whilst that at the same time by its weight subsided to the bottom. This too you see here likewise, which is of a white bright colour like Silver, is very ponderous, and on its upper or broader part, has the figure of a Star: And, indeed, it would be of a true metalline Nature, were it not for its brittleness, which makes it readily fly asunder, and renders it capable of being powdered. In this one Experiment, then, you have had a specimen of every thing that I have been explaining to you in the action of dry solid *Menstruums*. For in the first place, by a mechanical Attrition, all the three Substances were reduced into exceeding small Particles, and hence were rendered capable of being intimately mixed together. In the next place, the Fire melted, moved, and blended them all three with one another. Then, thirdly, the Salt of Tartar, and the Sulphur of the Antimony deflagrating together, in an instant produced a fixed Alkali, which immediately laid hold of the Sulphur of the Antimony, and, by an attracting force, acting reciprocally between them whilst they were thus intimately mixed together, this fixed Alkali and the melted Sulphur were united into one Body, which was still in a state of fusion. In the fourth place, from the same Operation, there arose likewise a repelling power between the metallic Reguline part of the Antimony, and the alkaline Salt, which never suffer themselves to be united in the Fire, but repel one another, and dispose themselves into distinct *Strata*, according to their respective Gravities. Hence, then, we see plainly, the reason why the metalline heavier part sunk to the bottom of the Cone, whilst the alkaline sulphureous one rose to the top, and thus gave rise to two new Bodies, viz. the alkaline sulphureous *Scoriae*, and a starry Regulus of Antimony. A mere mechanical Power, an attractive one, and a repulsive one, therefore, were the cause, in this Experiment, of the Solution and Separation. The mechanical Attrition, by reducing the Bodies into very small Particles, and thus vastly increasing their Surfaces, was the occasion of their having their points of contact greatly increased. The Fire proceeded farther to agitate them, and mix them together, excited, augmented, and continued their attractive and repulsive Power, dissolved the whole Mass, and all the parts of it, set fire to the Salt of Tartar, Sulphur and Nitre, and

and thus very much increased the strength of the Fire itself. The Tartar and Nitre, after the Deflagration was over, produced a true fixed alkaline Substance, the Nitre yielding a most acrid Alkali. This Alkali absorbed all the remaining Sulphur, and discharged the metalline part of the Antimony from it, which it had no effect upon. And lastly, the whole Mass help'd to increase the force of the first, whence arose a more rapid motion and concussion, and at the same time, a Smoke, and Soot, by which means 16 ounces and 2 drachms of the original 34, were dissipated and lost, the *Regulus* weighing only 3 ounces and 6 drachms, and the *Scoriae*, as I mentioned before, 14. If you have a mind, now, Gentlemen, to perform this Operation yourselves, you must be sure to do it with a great deal of caution, if you would expect it to succeed. For in the first place, if your Crucible is not sufficiently large, the Matter will boil up in melting, and run over the edges. If the Matter is not reduced to an exceeding fine Powder, it will crackle and fly about. If the Powder is not thoroughly hot, when it is thrown in, it will chill the Crucible, and split it. If you don't wait till the detonation of that you have thrown in, is intirely over, and the whole is grown perfectly red, nay, and is fluxed too, before you proceed, then the part that is not melted, will collect itself into a solid Crust upon the Surface, and will confine that which is underneath at the bottom of the Crucible, which being resolved in the mean time into an Alkali, Nitre, and Sulphur, will have the vertues of a true *Pulvis Fulminans*, and will in a little time be discharged with a most prodigious noise, and dash all to pieces; the danger of which can only be avoided by the cautions abovementioned. But again, if the whole Matter is not kept melted, and flowing like Water for some time in the Crucible before you pour it out, the pure *Regulus* will never be rightly separated from the *Scoriae*. If you don't make the Cone pretty hot, there will be danger of its splitting, when the melted Matter comes into it. If you don't rub it over with Tallow, the Matter often concretes with it, nor will suffer itself to be separated afterwards. If there happens to be the least drop of Water in the Cone, the Operation will prove exceeding dangerous, the Matter all flying about with a vast force and noise. If you don't pour the Matter in whilst it continues perfectly fluid, neither the *Regulus*, nor the *Scoriae*, will dispose themselves in their proper place: So many cautions are necessary to this one Operation.

These things, therefore, being premised, we may now examine a little more nicely the actions of *Menstruums*, both solid and fluid, upon their Solvents, so far as they may be understood and explained in a pure mechanical manner: And for the sake of that valuable set of Men the Mathematicians, it will be worth while to endeavour to set this Matter once in a proper Light.

How far the actions of *Menstruums* are merely mechanical.

And that we may do this most effectually, please to consider in the first place, that in all Nature, there is not any one Body that falls under the cognizance of our senses, whose parts cohere so tenaciously, or rigidly together, that they may not be separated from one another by a mere mechanical force, without the concurrence of any other cause. As an instance of this, let us take a Diamond, which has been called by this name, on account of its excessive hardness, which was described by the Ancients as being insuperable, and yet we see is forced to submit to the Saw of the Lapidaries, who can accurately too split it afunder, and at pleasure grind and polish it into various Figures:

The hardest Bodies are dissolved mechanically.

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But to this purpose you know, the Workmen make use of nothing but pure mechanical Instruments, and a motion of the same nature.

By the soft-
est Bodies,

But again, in this simple mechanical division of Bodies, the most fluid, and consequently to our senses, the softest, is capable of wearing away, and dissolving, the very hardest we are acquainted with. Drops of Water falling from on high, hollow the most rigid Stones, wear away Metals, and in short, diminish every thing they fall upon. The force indeed of single drops, appears to us as it were, nothing at all, and yet, when it comes to be constantly repeated, it produces very considerable effects. The softest Leather, by a continual Attrition, will polish the hardest Stones, Metals, and even Glass itself. The Surface of a wooden Wheel will consume any Body whatever, applied to it as it runs round, into invisible Particles. Hence, therefore, we may fairly conclude, that by a continued repetition of their action, the softest Bodies are capable of resolving the most rigid into such minute particles, as don't fall any longer under the notice of our Senses.

Whose Ele-
ments are
exceeding
hard.

It will help us now to conceive more easily of this surprizing *Phænomenon*, if we suppose, with some Authors, that the invisible ultimate Particles of all *Menstruums* whatsoever, ought to be looked upon as hard, and almost immutable, altho' the Body they compose seems exceeding soft to our Senses, on account of their receding very readily from their contact with one another. And this Opinion, indeed, by an induction of particulars, seems to be very much confirmed. The Elements of Fire overcome the hardness of all Bodies whatever; and yet they are prodigious small, and let their action be ever so violent, never appear to be in the least altered. No-body has ever observed the least change induced upon a Particle of Air, tho' this Element often brings about such various and powerful changes in other Bodies. Water, than which nothing is softer, whilst in a state of Fluidity, consists of Particles so immensely hard, that let them be compress'd by ever so great weight, or power, they have never been found to be altered. And the same, in the ultimate Particles of Earth, has appeared abundantly evident. The most subtil Spirits of Alcohol, how soft do they appear to the Organs of our Senses; and yet who, after a hundred Distillations, Digestions, and Compositions, has ever discovered the least sign of any alteration in their Elements. And as for the Spirits of Salts, as they are called, which are chemically drawn from them, and are so exceeding acrid, if we examine them, what an incredible immutability do we find in them, and consequently, as one may fairly infer, what an extreme hardness; tho' the Philosophers imagine them to be sharp like Needles, and hence easily mutable. That indefatigable Gentleman, however, Monsieur *Homborg*, having digested them for years with a constant Fire, and in close Vessels, has found them at last the very same without any alteration. *Du Hamel. l'Hist. de l'Ac. Roy. p. 497, 498.* That mild acid Vinegar alone, after four years, was changed into something of a different nature.

Hence Fluids
dissolve the
hardest Bo-
dies mecha-
nically.

There might other Arguments be produced to the same purpose, but what has been offered sufficiently demonstrates, that the ultimate Elements of the softest Fluids, if they are considered separately, are very durable, and therefore very hard. And as this is very evident, so likewise we clearly learn hence, that the ultimate Particles of *Menstruums*, if they are strongly pressed, and moved against

against the Corpuscles that compose the Solvend, may produce such an attrition as is capable, if sufficiently repeated, of wearing away, and dividing the greatest and hardest Bodies into their minute Particles; as we see in the hollowing of Stones by drops of Water.

And this happens particularly when the constant action of a strong Fire By Fire, produces such a perpetual collision, and attrition against these Surfaces. In every solution, however, thus supposed to be mechanically performed by the Particles of *Menstruums*, there is this considerable objection, that the Elements of the *Menstruum* being driven against the surface of the Solvend, would easily recoil again, and hence could not produce any remarkable effect.

And this, indeed, is in some measure true, but then their own proper Gravity, And Gravity. and the vast pressure of the Atmosphere, taken notice of in our History of Air, will apply them very powerfully to one another. At the same time, however, it is very evident, that where *Menstruums* act only by a simple, mechanical power, without any other concurring cause, they in reality effect but very little: And on the other hand, we know as certainly, that a strong external application of a Fluid to a Solid vastly increases its dissolving power, though all other circumstances continue the same. The Bones of an old Ox will boil a great while in an open Vessel, without any considerable alteration; and yet if they are boiled in *Boyle's* or *Papin's* Digester, they grow soft, and dissolve in a short time, tho' here there is only this difference, that in the last case the particles of Water are prodigiously compress'd against the Bones, and agitated upon them with a violent attrition.

Thus, then, we intelligibly enough conceive of the first mechanical manner Attrition upon the surface. in which some *Menstruums* act, viz. by wearing away Bodies by attrition upon their external surface. But when the Particles of the Solvent do not only thus separate the external Corpuscles of the Solvend, but act likewise upon the internal parts, and thus dissolve their whole Body; then these particles seem to insinuate themselves into the Pores of those Bodies, and there effect the very same thing upon the internal Surface that forms those cavities, as we made it appear they did before upon the external. There is one considerable difficulty, however, in this affair, and that is, rightly to comprehend the manner in which the Solvent thus enters into the Pores of the Body to be dissolved. This, I confess, is not so clear as a body could wish; because we have but a very few Experiments, where there is nothing but a pure mechanical action, and for this reason we are obliged to call in to our assistance some of those, where there is a concurrence of a mechanical, and some other causes together.

In the first place, then, there must be some proportion betwixt the Pores of the Body to be dissolved, and the particles of the *Menstruum* by which the solution is to be performed: For if these Pores are large enough to admit the *Menstruum* into them in a liquid form, then the case will be the same as we just now mentioned; if they are too small, then the internal parts will scarcely be dissolved. And hence it comes to pass, that when the particles of a simple *Menstruum* collect themselves by a mutual association into somewhat larger Corpuscles, they do not then so readily dissolve the Bodies exposed to them, as being scarcely able in this form to penetrate into them; though afterwards, if they are diluted with Water, and thus have their particles removed from con-

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tact with one another, they may then be able to enter into these Pores from which they were before excluded. This you see in the following experiment. In this Urinal I have an ounce of the best Oil of Vitriol, of my own preparing, depurated by distillation from all its *Fæces*, and by ebullition, from all its Water. This Liquor is so pure, that in very cold weather it congeals into solid, chrystalline Glebes, and melts again with the warmth of a thaw. This Oil of Vitriol I have heated to the degree of boiling Water, by keeping the Urinal some time in Water that was boiling. Into this Oil, now, I throw 5 drachms of hot Filings of Iron, and mix them together by shaking the Glass; and you observe what a prodigious rarefaction is instantly produced without any Fumes or Ebullition, the matter, indeed, which is of a grey colour, appearing puffed up, but continuing at rest. But please to take notice of this second Experiment. I have in this other Urinal 1 ounce of the same hot Oil of Vitriol, to which I now add three ounces of Water, heated likewise, that they may be mixed without danger of breaking the Glass, which would happen, if the Oil and Water were put together cold; for then the sudden heat produced would make the Glass burst asunder. Into these 4 ounces of Liquor I throw 5 drachms of Filings of Iron; and there arises, you see, a prodigious Ebullition, Effervescence, and a Fume, that has a smell like Garlick, and the whole Body of the Iron is perfectly dissolved into a green Liquor. In the same manner the famous *Bohn* and *Boyle* tell us, Silver and Lead will not dissolve in the strongest Spirit of Nitre, though if it is diluted with Water, they will be corroded by it immediately. But that you may be judges of this yourselves, please to attend to the following Experiments. In this Vessel I have 1 ounce of the strongest Spirit of Nitre that can be made, into which I put half an ounce of *Minium*, and they remain quiet, without any Effervescence, and in the cold will continue so a considerable time. Again, I have here 1 ounce of the same Spirit of Nitre, but diluted with eight ounces of Water: To this I add $\frac{1}{2}$ an ounce of *Minium*, and they remain at rest as before. But again, in this Vessel I mix 1 ounce of pure Silver with 1 ounce of the same strong Spirit of Nitre; nor do these discover any motion or ebullition. And lastly, in this Glass there is 1 ounce of this Spirit mixed with the same quantity of Rain-Water, into which I throw 1 ounce of pure Silver; and these you see, likewise, in this degree of Cold continue perfectly at rest. But as soon as ever, now, the Fire begins to put these four mixtures in motion, there is presently brought about an agitation, solution, and ebullition, which appears in the pure Spirit to be weaker and slower, in that which is diluted, brisker and more efficacious. See *Boyle* upon this head, in his *Philos. Ess. Bohn. Chem.* p. 156. Let us now, then, Gentlemen, consider what we can deduce from these Experiments to our present purpose. In the first place, then, it hence evidently appears, that acid Salts, when they are converted into Spirits, as they are called, may be diluted with a greater, or less quantity of Water. Secondly, that by the concussion of the Glass this dilution is so much promoted, that by this means the Water may be very equably mixed with the Salts, though before, the Acid stagnated at the bottom, and the Water rested quietly at top; as the pinguious *Striæ* in one part evidently demonstrate. Thirdly, that between every two saline Particles, as many aqueous Particles, as the Artift pleases, may be in this manner interposed, if he will only add a proper quantity of Water. That hence, therefore, in
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the fourth place, it may be effected, that these Particles, thus diluted, shall not any longer be united into saline Glebes, but shall separately swim about amongst the Particles of Water, with which they are intermixed. Hence, fifthly, these saline Elements, thus swimming about in the Water, seem capable of insinuating themselves into the very small Pores of the Bodies to be dissolved; inasmuch as they now exist in their smallest form. In the last place, it is probable, that these acid, saline Particles, when they were not diluted with Water, associated with one another, and thus were in some measure concreted into coherent, little Masses, which by this means became too great to penetrate into these little vacuities. These things, then, being duly considered, the opinion we just now offered seems sufficiently probable.

In the second place, if we would rightly understand the powers of those *Menstruums* that perform their effects in a mechanical manner, it is necessary, by all means, to consider the figure of the solvent Particles: For it appears, by the mechanical demonstrations of the Geometricians, that mechanical actions depend principally upon the figure of the acting Bodies. For a Body, remaining perfectly the same in all other respects, but only changing its figure, becomes fit to perform a great many things, which it was not capable of before. This I generally explain by this simple Example. Take an ounce of Steel, and form it into a Sphere, a Cube, a Knife, a Lancet, a Polygon, a Dagger, a Pyramid, an Adz, a Saw, or a File, and will it not in every one of these shapes acquire a new, and very different power from what it had before? The same Body, therefore, being variously shaped, acts always with a new power upon the Body which it is made use of to dissolve. But by this means it often happens, likewise, that the capacity of the Pores become fit to admit Solvents of certain Figures, rather than any others. And hence it seems to come to pass, that the reciprocal vertue betwixt the Solvent and Solvend, is often perfectly changed or destroyed, when either one or both have the figure of their surface altered. This, indeed, it is exceeding difficult to give an ocular demonstration of; as neither the ultimate Particles, or Pores of Bodies can scarce possibly be rendered visible: But if from what we observe in larger Bodies, we may be allowed by analogy to conclude concerning the more minute, we must infer, that this will likewise hold true in those Particles of Bodies which escape the distinct observation of our senses. Unless, perhaps, some persons may imagine, that the solvent Elements are not changable in any respect; though this I think does not appear so probable; as the Elements of Bodies seem to be one thing; those of Solvents another. In many, at least, it looks as if this mutability must be admitted. In the mean time, that a very efficacious power of acting arises between Bodies, from the mere figure of the ingredient, and admittent, the illustrious *Boyle* formerly evinced by the instance of a Key and a Lock, in which, solely from the size and figure, there is produced such a particular power of acting, as is peculiar to those two alone. Hence, therefore, we infer, that the proportion, likewise, between the figure of the solvent Elements, and the Pores of the Body to be dissolved, is the occasion of a great number of very particular effects in these merely mechanical solutions; and that hence, from the bulk and figure of these Particles, the most remarkable, corporeal changes are continually brought about. Lastly, by the figure alone of a given Body, very often are produced very surprizing effects, depending only upon that particular

The second.

conformation. If a metal Bell, for instance, is cast into a proper shape, how wonderful are its operations? Suspend it freely in the Air, and strike upon it only gently with a Hammer, and its whole *series* of Circles, quite from top to bottom, will recede from their circular figure, and every one of them run through an infinite number of *Ellipses*, till they come to their internal limits, and will then run out again beyond their first circular figure into elliptical ones, till they come to their external limits, so that alternately cutting one another, perpendicularly to their diameters in these circles, they describe by these undulations both ellipses and circles. But these excursions, now, are exceeding swift, and performed reciprocally backwards and forwards, and by this means agitating the Air, produce brisk undulations in this, likewise, to an incredible distance, and thus propagate sounds and tremulous concussions, by which alone very surprizing effects are wrought upon the Bodies of Animals, Vegetables, and Fossils. And all these changes depend intirely upon the formation of the Bell. The following Experiments, likewise, are usually referr'd hither, in which it is supposed the figure of the Solvent is altered, with respect to that of its Solvend. Take an ounce of the choicest Oil of Vitriol, and drop into it gradually six times as much of the purest Alcohol of Wine, prepared without any Alkali, shaking the Glass after every drop. Digest these for a considerable time in a tall Vessel accurately closed, and then very cautiously distill them till the mixture begins to grow black. When you observe this, fix on another clean Receiver, and patiently and prudently urge it with a very soft Fire; and there will rise in this gentle Heat a suffocating, sulphureous Phlegm, that excites coughing most violently, and with it a sweet, fragrant, volatile Oil of Vitriol, weighing almost six drachms, which must be carefully secured. *Hoffman. Obs. Phys. Chem.* If this, now, prepared in this manner, is poured upon Iron, it produces very different effects from what we observe from mixing this Metal with native Oil of Vitriol. The same, likewise, is true of the strongest Spirit of Nitre, made sweet according to art with three times as much Alcohol, and then put upon Iron. Nay, and that the purest Spirit of Salt, edulcorated in this manner, will not dissolve Gold, but will take away its colour, was long ago observed by the great *Boyle*. The same sweet Spirit of Nitre, too, will no longer dissolve Silver, though before it corroded it so greedily. These *Phænomena*, now, Authors of note have ascribed to an alteration in the figure of the corroding Elements; for whether you impute it to the combination with the Alcohol, or the distillation, or both together, the form of the corrodents, certainly, will be always changed.

The Third.

But whilst we are considering these merely mechanical solutions, there seems to be still a third cause, which may very much concur towards the activity of the Solvent; and that is, to suppose the ultimate Elements of the *Menstruum* to be endued with a proper rigidity, and to be able to insinuate themselves in such a manner into the Pores of the Body to be dissolved, that one part may be fixed in it, whilst the other stands out above the Surface. For if we imagine this to happen all over the porous Surface, and thus conceive it to be grown rough with these *Spicula*, which are thus inserted but are not able to proceed any farther; then if a motion is excited in the *Menstruum*, the agitated particles will strike upon the exterior parts of these Wedges, and that, every moment in various directions. Hence, then, must necessarily arise in these particles a power of cleaving and dividing asunder the

Corpuscles

Corpuscles of the Solvend; as we see timber cleft to pieces by the assistance of Wedges. And that this, now, is the case in *Menstruums*, is certainly exceeding probable; especially if we consider, that in these solutions those surfaces that were smooth before, almost always grow rough and unequal. And indeed in mechanical solutions, this third cause seems to be the most efficacious; as we can clearly conceive of the active power of those inserted, and variously agitated Wedges; as the ultimate Elements of the Solvent are infinitely numerous; and as the Pores of the Solvend are distributed through every point of its Surface, as appears evidently from the fineness of the Particles when they come to be separated.

Lastly, a fourth cause that promotes mechanical Solutions, is Fire, For this The fourth. it is that principally agitates, applies, and renews the application of the solvent Particles, whenever these happen to be qualified in the manner above-explained. This it is that, by its concurrence, puts the whole in action; without this the three other causes would be intirely without effect. A Wedge though it is fixed into a piece of Oak, has no manner of efficacy towards cleaving it asunder, if the external percussio of the Beetle is not superadded. And thus, tho' the Elements of the Solvent, in size, rigidity, figure, weight, and elasticity, are perfectly suited to the pores, resistance, and hardness of the Body to be dissolved; though they are brought into contact with it; tho' they have one of their extremities fixed into it, whilst the other part stands out above the Surface; I say, though all these circumstances concur together, they will be able to induce no change upon the Solvend, unless the active percussio of Fire comes in to their assistance. Nor does Fire only act thus directly upon these *Menstruums*, but it assists them, likewise, as it puts in motion and agitates the Air, which presses upon them with a prodigious weight, and thus applies their Particles to one another, by which concussio it produces an attrition upon the surfaces of the Bodies to be dissolved. And hence the elasticity, weight, and agitation of the Air excited by Fire, assists, likewise, the powers abovementioned; as does also concussio and attrition. This then, Gentlemen, is all that pure Mechanics can furnish us with, that I know of towards understanding the actions of *Menstruums*. This some Gentlemen, of great authority, have thought sufficient to explain all the *Phænomena* that have ever been observed in their Operations. But, with submission, though we are ready to acknowledge, that in all the actions of every kind of *Menstruum* whatever, all these mechanical powers are present, and do assist and co-operate; yet still we cannot for this reason allow, that they alone, without the concurrence of any other cause, are capable of perfecting the whole Operation.

Nay, on the contrary, we take the liberty to assert, that it very seldom happens, that any *Menstruum* whatsoever acts with all its energy, by the assistance of these causes alone. And this we think is so evident to an unprejudiced inquirer, that the incomparable *Newton* was obliged, from the observations he had made, to add some others of a quite different nature. But that the Geometricians may not charge us with asserting this rashly, and without sufficient grounds, let us examine the matter a little deliberately. When a Body, then, is immersed, and is at rest in a Fluid, endued only with mere mechanical properties, and this Body has no power, with regard to this Liquid, but a common mechanical

Mechanical
force alone
not sufficient.

mechanical one, what mechanical Operation will then naturally follow? Why the fluid Matter being at rest, will, from its weight, and the subtlety of its parts, surround and compress both the external surface of the Body, and the internal one of the Pores, which it is capable of penetrating into. And hence, according to the laws of Hydrostatics, the consequence will be nothing more than a bare compression of the parts, without any division, or so much as the least alteration of its figure; unless the Body should happen to be soft, and yield but little resistance, and at the same time should have its Pores full of a Fluid lighter than the surrounding one, and capable of being condensed or expell'd; for then, the Mass being condensed, would have its figure, bulk, and specific gravity altered, and by this means would rather come to a more settled state of rest, and cohesion, than to one of dissolution. But suppose, now, that by the application of Fire, the Elements of the *Menstruum* were put in agitation, why then, too, if both the Fluid and Body immersed, considered separately, are homogeneous, the effect of the *Menstruum* will be pretty nearly the same; for the Fire acting equally upon all the Elements of the Fluid together, will still continue to press the Body equally on all sides. When it is raised, indeed, to such a degree, as to make the Fluid boil, and produce those unequal and explosive motions that are the consequence of it, it may then, by these irregular percussions, rub off somewhat from the surface of the Body, especially if any Particles happen to stand out above the rest. But this, now, of how little consequence it can be of in the Solutions we daily see performed by *Menstruums*, every body that knows any thing of the matter must easily conceive; especially if we consider, that Hartshorn will not be so much dissolved by being boiled for a long time in Water, in which it is every way surrounded, as it will by being suspended in such a manner, as to be exposed to its Vapour; as the alchemistical solution of Hartshorn evinces. But then let me caution you, that if any Matter contained in the Pores of the Solvend should be dilated by the Fire, dislodged in Bubbles, and so break through the inclosures where it was confined, and thus divide the Body, this solution must not be ascribed to the mechanical action of the *Menstruum*, but to the rarefying force of the Fire acting upon this elastic Matter. Whilst I have seriously weighed all these things, I have frequently doubted with myself, whether the Air itself, in which are Oils, Salts, and Spirits, or any other *Menstruum*, whether fluid or solid, ever operates in their solutions of Bodies by pure mechanical Principles; especially considering that they themselves are scarcely ever simple and perfectly pure: And upon examination I have found, that there are intermixed with them all various parts of different powers, which have their proper and peculiar virtues, by which they attract, repel, and change Bodies after various manners. Whoever, therefore, ascribes more to a mechanical power than the All-wise Creator has allotted to it, is certainly in the wrong: This, as every thing else has its proper limits, within which if we keep, we shall act wisely, and may so far safely make use of this cause for explaining the Operations of the Chemical Art. These then, Gentlemen, are my sentiments upon this head; which the love of truth has drawn from me. How distant these are from the charge that has been publicly fixed upon me, that I pretend to explain all chemical Operations by mechanical Principles, you yourselves are judges. This certainly is imposing upon the World, and imputing to me

me what is vastly different from my way of thinking, and what I constantly oppose, as, I believe, there is no man living less pleased with this opinion than myself.

Having thus, then, dispatched the Doctrine of *Menstruums* that act by a mechanical power, I come now to examine those which execute their office by some particular vertue, and do not operate by any of those qualities with which the Author of Nature has endued Bodies in general. And these, in reality, are so numerous, that there are scarce any that do not come under this head. It will be necessary, therefore, to digest this vast multitude into certain Classes, prefixing to each of them some distinguishing character, to which they may be reduced. And this method will have this evident advantage, that it will both assist the memory, and give us an opportunity of referring any new ones, that may be found out, to some that were known before, and thus, from the affinity of their nature, easily understanding the force of their action.

Of *Menstruums* that act by a particular vertue.

Of WATER and WATERY MENSTRUUMS.

In the first place, then, I shall treat of Water, and watery *Menstruums*; which will make up the first Class.

Water, then, congealed with Cold, being mixed with dry or fluid Salts, volatile or fixed alcalious ones, volatile or fixed acid ones, and compound ones, as also with fermented vegetable Spirits, both dissolves, and is dissolved; and in this sense, therefore, why may it not be referred to solid *Menstruums*? This it does in the most intense cold, and always by this means excite a greater degree of it. See p. 97. and following, where this affair has been handled already, and therefore may be here properly omitted.

Ice a *Menstruum*.

The proper dissolving action of Water, however, strictly so called, begins then, when this Element continuing still in a state of fluidity, is in the very next degree to freezing. This, therefore, according to our former observations will be, when *Fahrenheit's* Thermometer stands at about 33 degrees; for then a hoar-frost begins to be formed in the Air. But that great Mathematician *Romer*, during the severity of the Winter 1709, is said to have observed at * *Gedanum* the same Thermometer, of which he himself was the first inventor, fall from the freezing point 33 to the degree 1; and consequently the Cold had then increased 32 degrees beyond a freezing one. But as this place is in 40 degrees North Latitude, and therefore 50 degrees from the North Pole; as the cold always grows greater and greater, the nearer you approach to the Pole; and as no body has ever yet been able to get thither, the excessiveness of the Cold proving fatal long before one can come near it: Hence we certainly know, that the Cold about the Pole must be greater than any that has ever yet been observed, though to what degree it rises there it is not possible to determine.

But rather when it is a Fluid.

This, however, which is sufficient for our present purpose, we may be absolutely sure of, that through the whole extent of Cold, from the degree 32 to those unknown limits, pure Water can never perform the office of a liquid

Its force different in different degrees of Heat.

* If our Author means *Dantzick* here, which is the only place that I know of that this word signifies, that lies in about the latitude 54, and, consequently, but 36 degrees from the Pole: This does not at all, however, invalidate the force of the argument.

Menstruum.

Menstruum. But as Water, now, by the application of Fire to it, may be heated to 214 degrees; hence its action, as it depends upon Fire, may be so far increased, but no farther, so long as it is upon the surface of our Earth, and exposed to the open Air; for under these circumstances it is not possible to give it any greater degree of Heat. If we remember, however, that Water is capable of receiving so much more Fire into it, as it is compressed with a greater weight of the Atmosphere, then we may clearly conceive, that the power of Water, when increased by Fire, in the deepest recesses of the Earth, may be so immensely great, that its dissolving force thus augmented may be greater than that of any other *Menstruum* that we are here acquainted with. But be this as it will, this we are sure of, that Water with us, as Water, has its dissolving power confined within 32 and 214 degrees of Heat.

But limited.

To the very great happiness, therefore, of the present age, we are able to measure the power of Fire upon this first *Menstruum*. And here it is very entertaining to take a view of the various methods of Nature's working in these different degrees of Heat; for in many solutions performed by Water, its dissolving power increases in proportion to the Heat to which it is exposed, and remits, and grows less again, as that is diminished. Thus we find, for instance, that Water 33 degrees hot will contain a certain quantity of Sea Salt dissolved in it, which, thus residing in it, will prevent its being frozen with that degree of Cold, in which pure Water begins to be congealed; for the interposed Salt seems to hinder the Surfaces of the Particles of Water coming into contact with one another: But if the Cold comes to be increased much above the degree in which pure Water freezes, then the salt Water likewise begins to be reduced into a less space, and the Salt, being pressed out by the contracted Water, begins to collect itself into little chrystalline Grains at the bottom of the Vessel. And if afterwards the Cold grows gradually sharper and sharper, the Water will by degrees discharge more and more Salt, till at last, being pretty nearly freed from it, it will be intirely converted into Ice: And here, in every degree of this increasing Cold, there will be more Salt separated from the Water than there was before. On the contrary, now, if in Water 33 degrees hot you dissolve as much Salt as ever it will take up, and then increase the Fire till you make it boil, throwing in a few grains of Salt upon every new degree of Heat, you will then find, that it will gradually dissolve more and more Salt, till the Brine begins to boil, but then will dissolve no more, though you keep it boiling for a considerable time. In the former case too it should be added, that Water which discharges its Salt by means of Cold, and then freezes, when afterwards it comes to be thaw'd, will dissolve again the same Salt that was separated from it.

As appears
by Experi-
ments.

But that you may have ocular demonstration of the truth of this, please to attend to the following experiments. In the first place, then, I take an ounce of pure dry Sea Salt reduced to powder, which I put into this clean glass chemical vial, and then pour 3 ounces of clean Water gently down the sides of the neck, and set the Vessel by in the degree of Heat which the Thermometer at present stands at. In this other Vial I have exactly the same quantity of Salt and Water as in the former, and hold it in the same degree of Heat, but this I shake very briskly about, adding now and then a small quantity of Salt, till it won't dissolve any more. This third Vial, likewise, is furnished with Water and

and Salt, as the other two. In this brass Kettle, now, which is upon the Fire, and has Water in it, I put the second Vial which contains the Water and Salt dissolved by concussion; and this third, which was not shook at all; and by gently increasing the Fire gradually heat the Water. You perceive, now, evidently, that as the Heat grows greater and greater, the Salt in the Vial that was not shaken, begins to be more and more dissolved, and that much sooner, and in a much greater quantity than that is in the first Vial, which I set by in the present heat of the Air: So that now, within a short time, the dissolution of the Salt in this vial which is at rest, is equally effected by the application of Fire to it, as you saw it was before in the second case by shaking the Vessel. But into this Vial, now, which has the Salt dissolved by concussion, as the Heat gradually increases, I continually throw in a few grains more of Salt, and this I continue to do till the Water in the copper Vessel begins to boil; and you see there is now a considerable quantity of Salt diluted in this Water, besides what it could dissolve, when the Vial was shaken about, though it was agitated very strongly. Having thus, then, thrown into this Vial, standing in the boiling Water, so much Salt, that the Water in it will not, in that degree of Heat, dissolve the last Grains I put in, I now take out the Vial with its Water thus saturated with Salt, by means of the Heat of the boiling Water, and wiping it clean, set it by, that it may gradually cool. As the heat of the Water, now, decreases, the Liquor which before was pellucid, begins, you perceive, to grow opaque, and turbid, a Pellicle forms itself upon its Surface, the Salt is precipitated to the bottom; and now it is reduced to the temperature of the surrounding Atmosphere, it has discharged almost as much Salt as it had dissolved more in the Heat of the boiling Water, than it had in the external Air. Having thus, then, observed these Experiments, please now to turn your eyes to the first Vial, which I set by with 3 ounces of Water, and 1 of Salt. And here you see part of the Salt is dissolved at the bottom, whilst a considerable part of it remains intire, as before. And that part which is thus dissolved is not mixed with the Water, but continues at the bottom of the Glass, in form of a heavy, pinguious, and, as it were, tenacious Liquid; and if it is not shook, will continue in that manner for a long time. If you shake it about, however, it dissolves in the appearance of little Eels, and becomes dispersed through the incumbent Water, nor ever separates from it again, and subsides to the bottom. This, now, being thus shaken from the bottom, another portion of the Salt is dissolved, and keeps at the bottom too as the former did, till it is agitated and mixed with the Water that is less salt, and swims at top of it; and the operation will be found to proceed in the same manner, till almost all the Salt that was put in is dissolved in this quantity of Water. In order, now, to make these Experiments, you see I have made use of two glass Vials, whose necks are so long, that nothing could exhale from the Brine in the belly of them, whilst they stood in the boiling Water; which is necessary to be observed: And you took notice, that I heated these necks, lest being exposed cold to the hot Vapour of the Water, they should fly to pieces.

If you please, now, we will take a view of some of the *Phænomena* which offer themselves to our observation in these simple Experiments, and which deserve to be properly considered. 1. Then it appears hence, that neither the Particles of the Salt, or the Water, are any ways changed in this Operation,

Corollaries
hence deducible.

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but

but that they are only so united together, that the Water is now come into contact with the Salt, in the same manner as the Elements of the Salt and the Water, separately considered, were in contact with one another; which kind of solution is called mere mixture. 2. That the Heat, in proportion to its Strength, increases the mixing power in such a manner that both the Solution is performed quicker, and a greater quantity of Salt is dissolved in the same quantity of Water; and this is constantly the case, so long as the Water is capable of admitting any farther degrees of Heat. 3. That aqueous *Menstruums*, which are perfectly saturated with Salt, if they are afterwards exposed to a greater degree of Cold, grow turbid, and deposite some saline Corpuscles; but upon being restored to their former Heat, recover their transparency, and dissolve again the Salt they had discharged. 4. That the Water is condensed by Cold, and the Salt dissolved in it compacted into chrystals, which melt again upon the return of the Heat. And this is true, to such a degree, that even Oil of Vitriol itself, that is perfectly dephlegmated, will continue fluid in a Vessel accurately stopp'd, but by an increase of Cold will be condensed into a solid Mass, which in a warm Air will dissolve again spontaneously. 5. That boiling Water, when it is thoroughly saturated with Salt, is heavier than that which is pure. Hence it comes to pass, that this Brine, whilst it is boiling on the Fire, appears by the Thermometer to be hotter than simple boiling Water. And hence, if a glass Vessel, with this Brine included, is set in boiling Water, the Brine can never be made to boil by the heat of that Water, but requires a greater degree of Heat before it will discover any signs of ebullition; tho' if pure Water was thus put in boiling Water, that likewise would boil immediately, as you have had the pleasure of seeing. 6. So far, therefore, the cause by which Water is a solvent *Menstruum*, is Fire, of which being deprived, it ceases to act. The truth of this, congelation evidently evinces; for this beginning at the degree 32, and descending 72 degrees lower (p. 100) the Cold through all the degrees of that decreasing Heat more efficaciously expell'd almost all kinds of Salts dissolved in the Water, and that to such a degree, that even Spirit of Nitre itself became concreted into icy Glebes. Hence, then, we evidently demonstrate, that as Cold gradually increases, it in proportion separates Salt more accurately from Water, and expells it perfectly when it comes to be thoroughly frozen. The same cold too deprives Water of the power of dissolving Alcohol; for in the Winter of the Year 1729, I exposed Ale, Wine, Vinegar, and Brine, in large flat Vessels, to that severe Cold, and the Frost reduced almost all the Water of these Liquors into a soft, spongy kind of Ice, and united the strong, generous Spirits into one Liquid; so that piercing the icy Crust, one might pour out a fragrant, and very sapid Liquor, now separated from the Water, with which it was before diluted. And the more intently the Cold was increased, this separation was constantly so much the greater. Cold, therefore, deprives Water of that property of a *Menstruum* by which it dissolves Alcohol and acid Salts. And it is exceeding probable, that the greatest Cold, possible in nature, would condense Water into such a Body, as would have no dissolving power at all; but such a Cold as this we are not acquainted with. 7. Hence we see, seventhly, that the proper power of Water, by which it is capable of dissolving Salts, or any other Bodies, and keeping them dissolved in it, and united with it, is

Not of itself sufficient for this purpose, but absolutely requires the assistance of Fire to be able to retain them in a state of solution. 8 What has been delivered, if it is applied to the animal Fluids, the human in particular, will be of excellent service to us, tho' it is but very little attended to. For among all the Fluids that are observed in a sound Body, Water is the principal, and much the greatest in quantity, and is always found intermixed with every one of them without exception. In this, therefore, the Elements of all the other animal Humours are dissolved, and circulate together with it, and are kept by it in a proper state of fluidity. And hence does it not evidently appear, what surprizing alterations this Water, which is so obnoxious to Cold and Heat, must induce upon these Humours? Examine the Blood drawn out of the Veins, and how wonderfully do you find it changed from itself by only being exposed to a gradually increasing Cold? Observe this Urine, which was made but a few hours ago by a healthy man that was fasting, and yet you see, in this cold season, it has already deposited a thick sediment at the bottom of the Urinal. But please to attend, now, whilst I gradually heat this Water over the Fire; and you perceive it dissolves the *Fæces* that were separated from it, and that in a short time it becomes just the same as when it was made. Hence, therefore, let us learn, what considerable alterations may be brought about in the living Body, by the variation of the heat of the Water contained in it. And whilst we are upon this head, I can hardly help absolutely inferring, that the dissolving Power which Water has as a *Menstruum*, always increases exactly in proportion to the augmented Heat, till it comes to a state of ebullition: This all the Observations we have proposed confirm the truth of.

But how dangerous is it, to please one's self with generals in Physicks, to recede ever so little from Experiment, or too hastily to come to conclusions? For there are other Experiments, and those not a few, which would induce one to believe, that the dissolving power of Water decreases in proportion as its Heat increases; an undeniable demonstration of which I shall now exhibit to you. In this Urinal I have some clean Water warm'd to the heat of the human Body. Into this I throw these Balls made of wheaten flower, work'd with Water into a soft, tenacious Paste; and don't you observe how they melt, are diluted, dissolved and mixed with the Water, and render it turbid? Into this other Urinal, now, which stands over the Fire, and in which the Water boils, I put some more of the same Balls; and these you perceive do not dissolve, but on the contrary, though they are thrown about by the force of the boiling Water, grow hard, nor have any of their Corpuscles beaten off. But again, with this Water, warm'd as before, I mix the white of a new-laid Egg; and you see it dissolves, and when it is diluted in the Water, disappears: But now as I make the Water gradually hotter and hotter, it begins, you perceive, by the Heat of this Water now in a greater motion, to be formed into fibrous concretions, and at last grows totally hard. Here, therefore, you have an ocular demonstration, that upon increasing the Heat from one certain point, the white of an Egg begins to harden, and grows continually harder and harder; and yet, from a certain limit of Cold, to that degree of Heat in which the coagulation first appears, upon every fresh addition of Heat, it is more and more diluted. The same thing holds true in Dough, our Blood, and that of other Animals.

The power
of Fire in
Water vari-
ous.

Hhh 2

Hence,

Substances
soluble by
Water in
every degree
of Heat.
First, Salt.

Hence, therefore, we must reduce into Classes those Bodies which are always certainly dissolved by Water, in every degree of Heat that can be communicated to it. Of this kind, then, are 1. All *Sal-Gems*, Fountain Salt, Sea Salt, Nitre, and *Sal-Ammoniac*, as well the *Cyrenaican* and *Aegyptian*, as the factitious. 2. All pure, volatile, alkaline Salts, whether spontaneously produced by putrefaction, or artificially procured by distillation, from Animals, or Vegetables. 3. Every kind of fixed alkaline Salts prepared from Vegetables by burning them. 4. All sorts of acid Salts that are naturally generated, either in the vegetable, or fossil kingdom. And to these we must add all vegetable Acids, procured by a proper fermentation, when by this fermentation there is a production of Spirits, and particularly when by a double fermentation those Spirits are prepared, which are commonly called Vinegar. And again, hither must be reduced those Acids, which by distillation are procured from most kinds of Woods, hard and ponderous ones in particular, as Oak, *Guaiacum*, Sassafras, and the like; as likewise all Vinegars, which, by distillation, have acquired the name of distilled Vinegars. The condensed Vapour, too, of burning Sulphur belongs properly to this Class; as well as that Acid which by a very strong Fire is drawn from Alum, Vitriol, Nitre, *Sal-Gem*, and Common and Fountain Salt. 5. Compound Salts, artificially produced by combining together alcalious and acid Salts to a perfect saturation. And these are very numerous, on account of the variety of the fixed, volatile Alkali's, the great number of vegetable and fossil Acids, and the diversity even of those of the same kind. But though all these, now, thus prepared, will dissolve in Water, yet let me caution you, that among these, that which goes by the name of vitriolated Tartar is dissolved by it with the most difficulty, and will very quickly again harden in it into a solid form. 6. Those singular and surprizing Salts, the Borax's, may likewise be diluted in Water, but not easily, and not without a large quantity of Water, and a strong Heat continued a good while; and hence, if either the Water is lessened, or the Heat abates, they presently form themselves again into solid Masses. 7. Native, vegetable Salts, produced from their Juices, by dilution, filtration, inspissation, and then letting them stand a good while quiet, as the essential Salt, as it is called, of sorrel, and others; all which are so easily dissoluble in Water, that they can scarcely be kept from melting of themselves. 8. And lastly, the Salts of Vegetables, which are generated from Wine, or the Juices of Plants perfectly fermented and depurated, adhere to the Casks, and go by the name of Tartars. These, if they are pure and hard enough, will continue dry in the Air, nor will dissolve in their own Wines. In Water they are diluted with difficulty, not without a great Heat, and twenty times their weight of Water; and as soon as ever either the quantity of Water, or the Heat necessary to keep it boiling is diminished, they immediately run into little solid Glebes. But except Borax, Nitre, Tartar, and vitriolated Tartar, all the other Salts will not only dissolve in Water, but are in their nature so averse to being kept dry, that they even run with the Water they attract out of the common Air; the pure acid Salts, and the volatile and fixed Alkaline readiest of all. As for the acid ones, certainly, it is exceeding difficult to exhibit them pure and dry, nor can it be done, except when it is vastly cold. And when you take fixed alcalious Salts out of a melting Fire, if they are exposed even to a dry Air, as soon as ever their Heat abates a little, they immediately grow damp

damp with the moisture they draw out of it. Hence, therefore, it evidently appears, that these Salts have a secret power of attracting Water into their dry and bibulous Substance. In the action therefore of Water, by which it dilutes these Salts, there are two Powers, which ought carefully to be distinguished from one another, conspiring together, one of which dissolves, the other attracts, and both in conjunction make up the efficacy of an aqueous *Menstruum*. Here, however, we must not omit taking notice, that there are some Salts, which when they are alone, are vastly greedy of Water, and yet when they are combin'd together form a third, which admits it with a great deal of difficulty. What, for instance, attracts Water more greedily than Oil of Vitriol; or what parts with its Water harder than the Alkali of Tartar? And yet if you accurately mix these two together in such a proportion, that the Composition shall by no sign distinguish itself to be either acid or alkaline, you will then have a dry Salt that will dissolve in Water but slowly. The same thing is observed to hold true in other saturated Salts, thus produced by combination, tho' perhaps in a somewhat less degree. But farther, in order to the perfect Solution of all these Salts, there is required a certain proportion of Water, which if you do not keep up to, there will be some Salt remaining undissolv'd at the bottom. And when Water, in a certain degree of Heat, is so thoroughly saturated with any particular Salt, that it will not dissolve any more of it, yet this *Lixivium*, thus impregnated, will in the same temperature take in some other Salt of a different nature. Thus, for instance, if you put Sea-Salt into Water that is saturated with Nitre, you will find the Water will dissolve a great part of it, tho' it would admit no more of the Nitre. And even then, when it is thus saturated with these two, you may afterwards add *Sal-Ammoniac* with the same success.

In the second place Water, as a *Menstruum*, dissolves all those Bodies, which from the large mixture of some Salt in them, are called saline. All these contain one of the Salts abovementioned, which makes up the greatest part of them, being intimately united with some other parts, which are neither Salts, nor of a saline nature, but belong to some other class of Bodies. To this kind we may reduce; 1. All natural *Sapo's* of Plants, which we have before taken notice of and explain'd. Of this sort we there told you, are the ripe juices of all kinds of summer fruits whatever; in all which the Water, Oil, Salt, and Spirit of the Vegetables, are most accurately mixed and concreted together, and all which are readily dissolv'd in Water. (See p. 39.) 2. Some singular concreted juices, different from the former, which are generated, and brought to perfection in some particular part of the Plant. Pulp of Cassia, Manna, Honies, and Sugars, are referr'd hither. These, indeed, may in some measure be reckon'd among the former, tho' they differ in the marks just mention'd, and evidently contain less Water. They are *Sapo's*, however, abounding in an Oil and Salt compounded together; and hence they are capable of being perfectly diluted with Water; even the Gums themselves not excepted. 3. The more liquid juices of Vegetables, which circulate in their proper Vessels through every part of them. Of this sort are the Fluids that run from the incisions made in the Birch, Walnut-tree, and Vine in the spring season. All these, of which in different Plants there is great variety, are *Sapo's* too diluted with a great deal of Water; and hence are thoroughly disposed

Secondly,
saline Sub-
stances.

disposed for a farther dissolution in an aqueous *Menstruum*. 4. All the humours of Animals hitherto observed, are very easily dissolved in Water, except the fat alone. None of these native Humours, however, are more greedy of Water than the Bile, as I learnt formerly, when I endeavoured, with a gentle Heat, to inspissate some of it fresh taken out of an Animal, in order to form it in Pills, and render it fit for keeping. But what was the consequence? Why the Mass spontaneously dissolv'd in the Air. 5. All Soaps made of an express'd vegetable Oil, a fix'd vegetable Alkali, and the igneous part of Quick-Lime, mix'd together by the help of boiling Water, and then by a proper coction inspissated into one Mass pretty closely concreted together. As likewise those Soaps which are prepared from distilled vegetable Oils, compounded with a very acrid igneous Alkali, very dry, and very hot, made likewise with the sharpest stony quick Lime: These are made by simply mixing these Substances together, and then exposing them in a low place to the open Air. To this head, likewise, belong those very choice Soaps prepared in a more curious manner, from the purest distilled Oil united with a simple volatile alkaline Salt, without the admixture of any Water, and perfected by a gentle, cautious, secret, repeated Sublimation, which then produces a most excellent Medicine. And lastly, those artificial Soaps the most subtil of all, made by a proper combination of the most perfect Alcohol, with an exceeding pure volatile alkaline Salt. These, if they are manag'd in a proper manner, are changed into a very volatile, saline, saponaceous, sulphureous Snow, which generally, tho' improperly, is called the *Offa Helmontiana*, by Raymund Lully, (*Spiritus Vini acuatius Sale-Ammoniaco*) Spirit of Wine sharpened with Sal-Ammoniac. To which likewise we may refer one more, which they prepared from Alcohol, and Tartar intimately united together, by some method which was kept a secret. In all these Soaps, Chemistry is continually finding out some new, and very efficacious *Menstruums*, which are used very safely to excellent purpose in the healing Art. Now this is particularly remarkable in these, that tho' Oils, when they are alone, won't admit of a union with Water, yet they will be dissolv'd by it when they are thus combin'd with Salts. Salts, when they are by themselves, attract Water; and so they do Oils. Hence, therefore, we learn the methods by which Oils may be diluted in pure Water. 6. To these saline Bodies may be referr'd, sixthly, with regard to an aqueous *Menstruum*, Vitriols as the Chemist calls them, or Chrystals, which are generated, when the Solvent Salts, Acids in particular, divide Metals into their smallest Particles, and adhering to them very tenaciously, become concreted with them into little Glebes, which are intirely dissoluble in Water, without any *Fæces* remaining, so long as they retain this true vitriolic form. Of this kind are the Magesteries, Sugars, Salts, and Vitriols, as they are called, of Gold, Silver, Lead, Mercury, Iron, Copper, and Tin, whilst they continue compounded of the acid Solvent, the Water, and the Particles of the Metals mixed together in such a proportion, that they remain clear and pellucid, like Glass, or Chrystal. The greater quantity now of the solvent Acid is added to the Metal formed into Vitriol, the easier always will it afterwards be diluted in Water. But if the Water is dissipated from the Vitriol by a gentle Heat, so as to render the Glebules opake, then the metalline Particles presently dispose themselves in such a manner, that they will not be so easily dissolved in Water

ter as they were before. Nay, if you continue to dry these Chryftals in this manner, they will at laft not be capable of Solution at all, tho' they will ftill retain a confiderable part of their folvent Acid. An evident inftance of all this we have in Mercury. If you take an ounce of this Fluid, which is abfolutely indiffoluble in Water, diffolve it in an ounce and a half of good Spirit of Nitre, and then fightly infpiffate it, you will have a Liquor which you may dilute with pure Water as long as you pleafe. When you have let this Liquor ftand quiet for fome time, it will at the bottom fhoot into Chryftals, which are exceeding cauftic, whitifh, and femi-pellucid, and will diffolve, inftantly, and totally, in Water. Dry thefe now into a white, yellow, red, fcarlet Powder, and then Water will not intirely diffolve them. In this refpect, therefore, Water diffolves thofe Metals no further than with regard only to the Acid that adheres to the metalline Surfaces; and for this reafon, the Water immediatly lets go the Metals as foon as ever they are by any means deprived of their Acid. Hence Metals, when they are diffolved in Acids, and then plentifully diluted with Water, may be rendered potable, be received into the human Body, be there mixed with its Fluids, and act upon its Solids, and by this means bring about thofe effects which it is able to perform upon either of them. And the effects, indeed, of thefe, are frequently obferved to be very confiderable; as by their acid and metalline quality they act upon both thefe parts very powerfully. This efficacy, however, remains no longer than whilft they continue in this fluid form; but as this depends chiefly upon the adhering Acid, when that is remov'd, their potability or mifcibility is deftroy'd likewife, and they are converted into a *Calx*, and Powder. Hence, then, we underftand, how long medicinal vitriolic Waters continue efficacious, viz. fo long as a folvent Salt is able to keep the diffolved Metal diluted and fustain'd in a large quantity of Water; for as foon as by the inactivity or poornefs of the Salt, they come to depofite an Ocre, they immediately grow flat and good for nothing. What now has been faid of the action of an Acid, with regard to Water, will hold good likewife in Metals diffolved in alcalious Salts; as Copper, for inftance, when it is diffolv'd in a ftrohg Spirit of *Sal-Ammoniac*, gives a violet Tincture, but being again deprived of its Salt, is wonderfully chang'd, and turn'd into a dirty Powder. The fame thing, likewife, is obferved in thofe Solutions, which are performed upon Metals by native or compound Salts. Thus *Sal-Ammoniac*, or Sea-Salt, will by certain methods diffolve Metals in fuch a manner, that they will afterwards fuffer themfelves to be diluted with Water: And fo long thefe likewife are capable of producing a great many effects in the human Body, but in fuch a manner, that here too their action is limited particularly to their folubility in Water. But as in every other part of Natural Philofophy, fo here likewife, it is very difficult to lay down a general rule that will in all cafes be found to hold good: For the Solution of Antimony, made with the ftrohgft Spirit of Sea-Salt which adheres to the corrofive Sublimate of Mercury, called Butter of Antimony, is thoroughly faturated with an Acid; and hence, according to the Doctrine laid down, one would be apt to imagine, that it might be eafily diffolv'd in Water; whereas, we find on the contrary, that if you pour Water upon it, the antimonial part turns immediately into an exceeding white *Calx*, which being fufed with a
ftrohg

strong Fire, produces a very beautiful *Regulus* of Antimony, which cannot be dissolved in Water by any Art whatsoever.

Thirdly,
terrestrial
Bodies dis-
solved in
Acids.

But to proceed to those Bodies which are purely terrestrial. These likewise, if they are first corroded by Acids, may be perfectly diluted in Water, and lie there so concealed, that the whole Liquor shall appear perfectly pellucid; and hence these too are capable of operating in this form. Take Chalk, for instance, when it is plentifully corroded by an Acid, and you may dilute it in Water at pleasure. And, indeed, I scarce know any Earth that may not be dissolved in some Acid or other, and under this change impose upon our Senses. Hence, therefore, we may conclude, how little we can judge of the purity of Water, with respect to any Earth that may be contained in it, purely from its perfect transparency: Nay, the true ultimate Earths, produced from the Bones, Flesh, Shells, and other parts of Animals, may be thus dissolved in Acids; and therefore, all these too, may, in this sense, be so far diluted in Water itself, and afterwards, by various methods, be recovered from it again.

Not Alkali's.

But tho' earthy Substances, when they are thus corroded by Acids become by this means dissoluble in Water, yet we see on the contrary, that when they are intimately united with Alkali's, they are no ways capable of this Solution. This we see evidently in Glass, which is compounded of an Earth and an Alkali intimately blended together, whose union the closer it is, the less will Water be able to affect them. What a vast difference do we here find then in Earth, with regard to its Solution by Water, as it is corroded by one of these Salts, or the other? Alkali's dissolve it more subtilly into a fix'd, pellucid, very hard Substance, which so powerfully resists the dissolving power of Water, that there is no Substance, which in this respect, exceeds it. It appears to me, however, still more surprizing, that the very subtil, volatile, alkaline Salts of Animals, should by their union with an Earth, form a Mass that will bear the action of boiling Water without being dissolved: But the Stone that is generated in Animals is such a Body, consisting of these Principles, and an Oil combined together. This, to the great unhappiness of many poor creatures, in whatever part of the Body it happens to be formed, is capable of propagating itself, and increasing in its magnitude; for it has a power of absorbing and uniting to its Mass, a Matter similar to itself, from those animal Humours which are nearest to putrefaction, as the Bile, and the Urine, in which the Salts become almost alcalious; and these again lay hold of the fine Particles of Earth that are abraded from the human Body in the course of circulation, and thus by associating with them, produce new stony Elements, and thus continually increase the terrible monster.

Hence we
learn the
reason of the
natural acti-
on of Ani-
mals.

Whilst I seriously now consider these things, I can't think but there appears an evident reason, why the All-wise Author of Nature, has made all the Elements of Animals, a very few excepted, of the acescent kind: For the acid Salts, by this means, predominating in the Stomach, dispose the Nutriment to a much happier Solution than the contrary wou'd; as the hard parts of the Food for their cohesion depend principally upon an Earth, and hence wou'd by alcalious Salts be reduced with more difficulty into a liquid Chyle. But as soon as ever now the Chyle is prepared, and from this there is a matter to be separated, that is proper for the formation of the Solids, then this acescent quality,

quality, necessary before in the Chyle, is intirely altered, and the Salts become of an alcalescent nature, which, uniting with the terrestrial Elements they meet with, compose a Mass not dissoluble in Water, but fit to contain and keep the Fluids within their proper bounds. Bones, we experience, if they are immers'd in alcalious Fluids, retain their firmness; whereas, if they are kept in Acids they grow soft, even so far as to become flexible, as the great *Ruyfch* told me he had often taken notice of in his anatomical Inquiries. This, it is certain, is very evident, that when the power which the human Body has of converting Acids into Alcalescents, comes to fail, then the Bones, Cartilages, and Teeth, become lax, weak, soft, and flexible; as in ricketty Children, in particular, falls continually under every ones Observation. Hence may Surgeons and Physicians learn, how imprudent it is to make use of the sharper Acids for whitening the Teeth; for tho' they flatter us with a present beauty, yet the Teeth by this means soon grow insensible, loosen, and drop out. How much better, therefore, for this purpose are the milder *Lixiviums* of fix'd Alkali's well diluted, by which the earthy Particles of the Teeth will be no ways injured.

After these, Sulphurs offer themselves next to our Examination, which tho' they are absolutely indissoluble in Water, so long as they are alone, yet suffer a perfect solution in it when they are intimately united with Alkali's. And hence again we may best understand the nature of sulphureous Waters; for what I observed to you before concerning metalline medicinal Waters, holds true here likewise. But volatile alkaline Salts also, can so resolve Sulphurs, as to render them capable of being diluted with Water: And hence it is evident, that Water assisted by Alkali's, may be able intirely to dissolve Sulphurs. And as this happens often in those Sulphurs that lie intimately concealed within Metals, and Semi-metals, by this means, tho' before they were latent, they then come to light, and discover themselves openly. And hence it comes to pass, that such Preparations, which are trifling to Persons acquainted with these things, are sold about for the profoundest *Arcana*: And in this manner even Princes themselves have been imposed upon. Thus we saw a Liquor prepared from Antimony, sold under the grand Title of a *Panacea*. A few drops of this taken in a glass of Wine, was immediately to cure diseases without any sensible effect: And, indeed, in some cases it was of service. But these secrets, when they come to be known, generally lose all their reputation, and these monopolizers no longer enjoy the gain of their boasted mysteries. After a proper Examination of the matter, I found this to be the Preparation. Upon native Antimony, reduced by long rubbing to a very fine Powder, pour twice the quantity of Oil of Tartar *per deliquium*, or the Alcahest of *Glauber*; then digest them together in a tall Bolthead for a considerable time, and pretty hot, and the liquid Alkali will gradually dissolve the Sulphur that lay concealed in the Antimony, and thus will extract a red kind of a Tincture, which has an igneous taste, a disposition anti-acid, is heating, aperient, diuretic, and diaphoretic. But to confess ingeniously, one may at once have as good a Medicine, by boiling common powder'd Sulphur in a *Lixivium* of a fixed acrid alkaline Salt; as this Sulphur is perfectly of the same nature with that in the Antimony; and as the metalline part of the Antimony is no ways affected by the Alkali. If you take powdered Antimony too, and according to art manage it with an alkaline Spirit, prepared from *Sal-Ammoniac*, you will thence likewise procure a golden sulphu-

Fourthly,
Sulphurs u-
nited with
Alkali's.

reous Tincture, as formerly the illustrious *Boyle* plainly made appear, that such a one might be prepared with simple Sulphur. But to what purpose is it to discover these cheats? Mankind love to be deceived; the rich frequently don't value things except they pay for them; and as for avarice, and extravagant pretensions, there's no pretending to restrain them.

Fifthly, the
most tenaci-
ous Refins.

Those Bodies, likewise, that consist of so tenacious a *Gluten*, that they absolutely resist the power of Water, may nevertheless, by being intimately united with either fixed or volatile Alkali's, be brought to be intirely dissolved in it; for by this means they lose their tenacity so repugnant to this Element, which they then admit betwixt their separated Particles, and so suffer themselves to be diluted by it. And hence we observe, that the putrified Urine of Animals, the *Fæces* of burnt Wine, all sorts of Soaps, Bile, Honey, Sugar, and the Yolk of Eggs, if they are mixed with these Bodies, make such an alteration in them, that they afterwards become dissoluble in Water; so that the power which Water has of washing and scouring, depends almost upon these alone. To this head belong Oils, Balsams, Colophonies, Refins, and Gum-Refins, all which at last come by this means within the reach of the efficacy of Water, tho' they were perfectly indissoluble in it before. These then, Gentlemen, are the chief things that occur to me concerning the power of Water, as a dissolving *Menstruum*, that I can honestly deliver to you as matters of fact; nor do I know any thing more upon this head, but what may be referred to what has been delivered. I am well enough acquainted with those things, which the top Masters of this Art have advanced in their Writings; but the love of truth, and that integrity which is the distinguishing character of a good Man, and which I wou'd endeavour to have a proper regard to, won't suffer me to lay them before you as true. For to deal honestly with you, I am in doubt myself, whether they have not attributed more to their inventions, than was really in them. But let that be as it will, for my own part, I confess ingeniously, that I never have been able to discover those singular *Arcana*, which they make such a boasting of. If you please, however, I'll just mention to you the Doctrine of *Van Helmont* upon this Subject; and that asserts plainly, that all Bodies are by the *Alcabeft* alone converted into a Salt, that has perfectly the Weight of the former Body, and may be intirely dissolved in Water. If this was the case, it must necessarily follow, that the power of Water must extend universally over all Bodies: Nor, indeed, to those who suppose that all things were produced from Water, is it so surprizing, that all Bodies whatever should be resolved into Water, Fire alone excepted, which, perhaps, for that very reason, they suppose not to be corporeal. I observed to you, indeed, myself, when I was explaining the mechanical power of Water in Solutions, that this, tho' of so exceeding soft a nature, if it falls from high, will in time divide every kind of Body whatever into exceeding small Particles; but that these, when thus separated by the motion of the Water, continued afterwards mixed with it, I cou'd never understand. I mentioned likewise what Monsieur *Homborg*, a Gentleman of uncommon assiduity, and undoubted veracity, has told us concerning Water's dissolving all sorts of Metals by being rubbed with them: But I cautioned you at the same time, that the Air had a free communication with them, which always makes an addition of almost every kind of Salt, especially in the Laboratories of the Chemists. For my own part, Water seems to me to furnish only a Vehicle for the Elements of

of Bodies, by which they may be capable of entering into Animals and Vegetables, and there be mixed and applied, and bring about whatever is necessary, either for the support of their life, or increase of their magnitude: If this alone is wanting, the whole remains a dry unactive Mass. And this seems to be the extent of its power.

The Doctrine, then, of Water, as a Solvent, being thus laid down, it will be necessary to say very little of watery *Menstruums*; as it would be almost only repeating the same things over again. A few Observations, however, which perhaps deserve to be taken notice of, I shall here subjoin.

Hail falling in Summer time, after great Heat and Thunder, and caught in a clean Vessel, has a different power from any other Water whatever; for this, of all Water, is the purest, as it was carried to a vast height in the Air, was congealed in the upper Regions of the Atmosphere, and thus in a solid form descended to the Earth.

Snow that falls in Winter, when it is exceeding cold, and there's no Wind, if you collect it in a high sandy desert place, and take it just from the top as soon as ever it comes down, produces the purest Water next to Hail.

Dew is a confused mixture of a great many things together; for in this are aqueous, spirituous, saline, and oily Vapours, and dry Exhalations of every kind whatever. And on this account it differs prodigiously from every other aqueous *Menstruum*: For it is generated only after a long continued Heat has scorched up the Earth; and consequently, when the Rays of the Sun, by their great strength, have carried up into the Air Particles more fixed than those of Water, which afterwards, when the Heat begins to abate, descend again upon the Surface of the Earth, Water, Plants, and Animals, and fill the dry and parched ground with a fresh supply of moisture. And hence, as I told you before, the virtues of it can scarcely be determined, or reduced under any head. And indeed it is a collection of such different Principles, that I don't wonder many persons should have imagined that there lay concealed in Dew, the latent Matter of a universal Salt, from which might be produced a Salt, which they call'd (*Congelatus mundi Spiritus*) *The congealed Spirit of the World*. But I pass by these things, to proceed to the other *Species* of *Menstruums*, adding nothing more than this one caution, that the Water in the Air very often performs the office of a *Menstruum*, where persons unwarily imagine, that the effects are owing to the proper efficacy of the Air.

Of Oils, and oily Menstruums.

Of the Character and Nature of Oils, I treated before, in the History of Animals and Vegetables, when I laid before you the different parts into which their compound fabrick might be resolved, p. 38, 43, and again, when I was examining the *Pabulum* of Fire, p. 175, 208, Oil then, to be considered now properly as a *Menstruum*, is a fluid Juice, or that may by a gentle Heat be rendered so, pinguious, inflammable when it is hot, and by no means miscible with Water. If any one imagines, that Alcohol ought to be ranked among the Oils, 'tis excepted only by the last property, as this will readily enough mix with Water: In all the other qualities of Oil, it perfectly agrees with it. All Oils, now, that have ever fallen under our Observation, are either native, as they exist in the Bodies they are generated in; or are prepared by

Art, the chemical one in particular, and then are always changed from their natural disposition. Nor can we help making this distinction between them, as on account of their surprizingly different efficacy as *Menstruums*, they are absolutely distinct from one another. Oils, then, or native oily Juices, are every where discovered as such, both in the Fossil, Animal, and Vegetable Kingdoms: When Art, which makes some alteration in them, is called in to separate them from their proper repositories, it effects this, first by boiling pinguious Substances in Water, by which means the Fat being melted, and freed from its confinement, rises to the top of the Water, and may be there collected, not a great deal altered from its proper nature. A second method of procuring them, is by pounding the oily Substances very well, and then putting them between two hot iron Plates, and with a Press pressing out the Oil. And in this case too, if you don't make the Plates too hot, the Oils will be very little different from the native. Sometimes they are separated likewise by bare melting them; and then the Bodies that abound with the oily Matter, are gently torried with a proper Fire, by which means their Oils and oily Substances are forced out, and so collected. This, in the Preparation of Pitch from the Coniferous Trees, is sufficiently evident. Upon this head the Treatise of *Axtius* deserves to be consulted. Lastly, these Oils are drawn from Bodies by Distillation, and that either by carrying them up by the help of Water, or Fire alone; or drawing them off (*per latus*) obliquely, as in the retort; or determining them downwards, which is called *per descensum*.

That do not
congele.

In these last Oils, which for the future we shall call distilled Oils, it is almost constantly observed, that they have never been found to have been frozen in the greatest degree of Cold, but have always retained their fluidity. But among the expressed Oil, some have been observed to harden with a sharp Cold into a solid Mass, composed of little Spheres united together, as is sufficiently known in Oil of Olives, Rape Oil, and many more; whilst others, as we see in Linseed-Oil, won't congeal even in a severe Frost. With regard now to this remarkable difference in these Oils, I have not, upon the most careful Examination, been at all able to discover what should be the cause of it: I refer it therefore to some secret quality, which we are forced to acknowledge, discovers itself only by Experiments, nor can be reduced to any known Law. It is a vast happiness, however, to mankind, that such a matter should have this property of continuing liquid in a most intense Frost, which at the same time, by means of a Wick once set on Fire, is capable of supplying us with light. But here we must farther observe, that the proper dissolving action of those Oils that will thus freeze, begins then only, when they are in the very next degree to congealing, but still appear in their liquid form: As therefore, some of these Oils freeze sooner than even Water itself; hence their dissolving power is, with respect to Cold, included within a narrower compass than that of Water. Those Oils, on the other hand, that keep fluid in the greatest natural Cold, always retain their dissolving faculty. Hence, therefore, it appears at one view, that it is impossible to fix any one certain point of Heat, from which the power of Solution of all Oils in common shall begin; tho' this in any one *Species* of Oil may be nearly determined, when once it has been accurately observed. If we consider now this property of Oils, how surprizingly do we find, that Oil of Linseed, tho' it retains its fluidity in the severest Frost

Frost, has really at that time no more heat in it, than the hardest Ice, or any other frozen Oil?

But farther, if you apply Fire to Oil, and increase it very cautiously and gradually, when it comes to a heat of 212 degrees, which is that of boiling of Water, it is then very far from boiling. Water, now, when it once comes to boil, cannot, by the application of the strongest Fire, have any more heat communicated to it; but Oil from the degree 212 grows gradually hotter and hotter, and before it boils is found to have admitted 600 degrees. No wonder, therefore, that boiling Oil should be so much hotter, and burn more terribly, than boiling Water. But here, too, we observe, that all Oils, if they are exposed to the same Fire, don't boil equally soon. Those, for instance, that are lighter, and more subtil, boil easier, and acquire less heat; whilst others take up more time, and grow hotter: Thus rectified Oil of Turpentine boils pretty soon; Linseed Oil with more difficulty. Hence, then, we perceive how difficult it is to determine the power of Oil as a *Menstruum*; for in Oil of Linseed, for instance, this power begins at the greatest degree of known Cold, and increases to the degree 600, and in every degree of increase it always acquires a new active virtue, and that, whether you apply it to the same Body in different degrees, or to different Bodies in the same degree, or different ones. In both these respects, therefore, you see there is an infinite latitude. But to make these things evident by ocular demonstration,

In the first place, then, you see this brass Kettle, which contains some pure Rain-water. Into this I set three Boltheads, as near as possible of the same size, and figure, and filled nearly to the same height, one with Alcohol, another with distilled Oil of Turpentine, and the third with Oil of Olives: And in the Water, with them, I place one of *Fahrenheit's* mercurial Thermometers. I now apply Fire under the Kettle, and keep the Water continually stirring, that it may be heated as equably as possible. The Water in the Kettle, now, has at present acquired a heat of 175 degrees; and now you see the Alcohol in the first Glass boils pretty strongly; this, therefore, I remove. The Water being kept frequently stirred, and growing hotter and hotter, has now arrived to the degree 213; and that you see, now, boils likewise; nor does the Mercury in the Thermometer dilate itself any farther, though, as you observe, I increase the Fire, so as to make the Water boil very violently. But the Oil of Turpentine, now, does not give the least sign of any ebullition in the second Glass; nor the Oil of Olives in the third. Here, then, you perceive this surprizing difference: Alcohol, though a very subtil, inflammable Oil, boils a great deal sooner than Water; Oil of Turpentine, which is so much lighter than Water, and pretty subtil too, is not at all put in motion with the heat of boiling Water, though this Oil is inflammable likewise; nor has the boiling Water more effect upon the Oil of Olives: Neither inflammability, therefore, nor levity, nor volatility, can be the occasion of this difference, since Oil of Turpentine is so volatile, that it rises in distillation with boiling Water.

But please to attend to a second Experiment. With the very same Apparatus as before, instead of Water, I have put in the Kettle the strongest Brine of Sea Salt that can be procured by boiling Water. To this, now, I apply Fire, as in the other case, and keep the Brine stirring, too, in the same manner. You see, now, here again, that as soon as the Brine comes to be heated

Admit of a great deal of Fire.

This appears by one Experiment.

Another

ed to 175 degrees, the Alcohol boils as before ; which therefore I take away. The Thermometer is now risen to the degree 218 ; and now the Brine begins to boil, likewise ; which, therefore, you perceive requires 5 degrees more to bring it to this state, than pure Water. The Thermometer, however, in this case, will still continue to ascend gradually a little higher ; because in this strong ebullition the Water continually evaporates, and the remaining Liquid of consequence grows denser, which at last would be nothing but mere Salt. In this Experiment, therefore, when we have once observed the degree of heat at which the Brine begins to boil, it is sufficient. The Oil of Turpentine, in the mean time, and the Oil of Olives, discover, as yet, no signs of ebullition.

A Third.

But to proceed to a third, which I shall perform with a great deal of caution. In this small Vial, the Bulb of which is of an equable capacity, and the neck pretty long, I have put some Oil of Turpentine, which fills $\frac{2}{3}$ of the Bulb. The whole Vial, now, both Bulb and Neck, I heat gradually and equably, lest otherwise it should fly when it comes near to the Fire. The Glass, then, and Oil being thus heated, I hold it over the clear Coals in this Chaffing-dish, bringing it continually nearer and nearer to the Fire. Are not you surprized, now, that it don't yet begin to boil ? But observe it, now it just touches the Fire, and you may perceive an ebullition : And you see, too, it don't boil gently, but vehemently ; and at the same time makes a considerable noise. And though I have now removed the Vial from the Fire, you observe the agitation, noise, and ebullition, continue a good while in the Oil, though both Alcohol and Water presently cease boiling when they are taken off the Fire : But you'll want to know what degree of Heat this Oil acquired before it began to boil : This you may discover in the following manner. Take some Linseed-Oil, in a brass Vessel, place a mercurial Thermometer in it, and the Vial with the Oil of Turpentine, and set it over the Fire ; you will find, then, that the Oil of Turpentine in the Vial will boil a good deal sooner than the Oil of Linseed in the Vessel, and at the same time the Thermometer will indicate the degree, which, if I remember right, I found to be 560. As this Oil, now, in boiling sends off its more volatile parts, the *residuum*, which will be thicker, will require presently a greater heat to cause an ebullition. And this more difficult ebullition, and necessary communication of a greater Heat, will increase every moment, in proportion to the spissitude of the remaining Oil. Hence, therefore, it will not appear surprizing to the Physicians, that these thick Oils, when they are put in agitation, produce such a prodigious Heat ; which Observation, if I am not much mistaken, is both exceeding beautiful and useful. But these agreeable speculations carry me beyond my purpose.

A Fourth.

But to proceed to a fourth Experiment. I have here in this Vial some Oil of sweet Almonds fresh drawn, which, after all the cautions observed in the former Experiments, I at last set on the open Fire, till the Glass is ready to melt ; and now you see the Oil begins to boil, not before. And the motion you perceive of this Oil, when it boils, is quiet, equable, and without noise, and continues so to the end ; and yet the Heat of this is more than 600 degrees.

The quantity of Fire in Oils.

From the consideration, now, of the Latitude in which Oils will bear the application and increase of Fire, which is almost three times greater than that of boiling Water, we very easily perceive, that the dissolving power of Oil, considered

considered as it depends upon Fire, must be proportionably so much greater in Oil than in Water. For as most Oils retain their fluidity at the first degree of heat in the Thermometer, in which Water begins to freeze at about 33; and as the compass of Heat which Water can pass through, whilst fluid, is but 180 degrees, viz. from its freezing point 33, to that of its ebullition 213, whereas from the first degree of Linseed Oil's fluidity to that in which it boils is at least 600: Hence it evidently appears, that the possible power of the Fire in that Oil, is to the same in pure Water, as 10 is to 3; which what mortal living could possibly have discovered *a priori*? But if we consider farther, that many Oils, when they are inspissated, will take in still a good deal more Fire, we see, that the power of Fire in Oils will be still farther extended.

In the mean time, however, this is most certain, that if any of the parts, or the whole Bodies of Animals or Vegetables are accurately immersed in Oil, they will keep them without alteration, secure from dissipation, fermentation, or putrefaction; and they may be preserved in this manner, though the heat of the Air should be as great as has ever been naturally observed. Insects, too, that are so very troublesome in this particular, will be kept off, likewise, by the Oil that swims at top; so that by this means they will remain intire, as long as they are thus defended. And, indeed, when these substances have been so long immersed in Oil, that they are perfectly penetrated in all their parts, they then seem to have acquired an almost incorruptible nature, and may be preserved a prodigious while. This appears evidently in Bodies that have been thus treated; upon which principle depends chiefly the art of embalming; of which by this means we discover both the origin and efficacy.

The power of warm Oil upon Animals and Vegetables.

But when Bodies, now, are suddenly thrown into boiling Oil, they presently acquire a hard, and almost stoney Crust over them, which is of the same colour that they get by being exposed to the open Fire, viz. yellow, red, and at last black. The other part, in the mean while, that lies under this Crust, being agitated by the prodigious heat of the ambient, boiling Oil, and having its motion at the same time repell'd, stopp'd, and as it were suffocated, is surprizingly altered, concocted, digested, and maturated, and at last grows consolidated, and is exceedingly well fitted for keeping a long time. But when the substances, that are thus immersed in Oil boiling hot, are full of aqueous Juices, as Flesh or Fish dried on the out-side, then these humours being agitated under this Crust, with more than a boiling heat, the parts grow very tender, retain all their juices, and become exceeding well fitted for digestion and nutrition. And Meats thus prepared too, are very durable; for all the principles of Bodies, treated in this manner, being intimately united together, and helping to render one another more perfect, produce a substance secure against any inconvenience from external causes.

The effect of boiling Oil upon the same.

From what has been said, then, we may by the way deduce some truths, which one would scarcely have expected. In the first place, then, it appears hence, that the degree of heat which Fire is capable of communicating to Bodies, is not in proportion to the densities of the Bodies heated. Secondly, that the same Body, if it is gradually rendered denser, will admit a greater quantity of Fire, in proportion to the increase of its specific gravity. Thirdly, that a Body's being capable of taking in a larger quantity of Fire, does not depend

Corollaries hence deducible.

depend upon its combustibility. Alcohol, when it once comes to boil, admits no more Heat or Fire; nothing in nature is more combustible than Alcohol; and yet there is no Liquor that we know of, which will not receive more Heat than this. Here again, then, we see how difficult it is to come at general truths; and that the true properties of Bodies must be determined by an examination of the particulars. From these things, then, thus first demonstrated, we may deduce a great many Corollaries, of which this is a remarkable one, that we may dissolve some Metals intimately in some sorts of Oils, so that by this means there shall arise a Mixture, which will not easily again be resolved into its principles. By this Art there have been some valuable secrets found out, both in Mechanics and Physick, which we could not want, without a good deal of inconvenience.

Upon Me-
tals.

But to return to our Experiments. A fifth, now, I am going to make before you, that I never exhibited in this manner before. Into this Vial I have put half an ounce of *Minium*, and now pour on it an ounce and a half of Oil of Olives, which, by shaking, I mix thoroughly together. And you see I have made choice of the same sort of Vessel I made use of and described before, and have used the same caution in gradually heating it at a distance. I now hold the Bulb of it just over the Fire, till the Oil begins to boil, and you perceive, now, the Liquor is boiling hot, the powder of the *Minium* is dissolved, mix'd with it, and compounded with it, into one Mass. But at the same time, you observe, likewise, that this Mixture was not effected till the Oil was brought to a prodigious degree of heat, which the *Minium*, then, was no longer able to resist. Hence, then, we learn how to prepare a Balsam of Metals, and a Cement, that will powerfully resist Water. But a sixth, which is a new one, likewise, and more surprizing, I perform in this manner. Into this Vial I have put half an ounce of Shot, and I now pour upon it an ounce and a half of Oil of Olives; and, with the same caution as before, set it over the Fire. Who, now, would have believed what we at present see? viz. that the Lead melts and runs, like Water, at the bottom of the Glass, though the Oil don't boil, nor so much as emit any Vapour. Hence you see Glass is melted with more difficulty than Lead. But now, whilst I hold it in a stronger heat, and the Oil begins to boil, you observe, the Metal begins, likewise, to be dissolved by it. Glass, however, you see, will not be dissolved by Oil, let it acquire whatever degree of heat it is capable of. Hence, therefore, we see why melted Lead burns less violently than boiling Oil; and for this reason it will bear being handled immediately, if the person's hands are incrustated over with a very dry Chalk. If any person, here, has a mind to imitate this Experiment, let me warn him to do it with a great deal of caution, or otherwise it may prove a very fatal one: For if a drop of Water should any ways come into the Vial, it would all burst to pieces, with a vast *impetus*, and bring the Operator into imminent danger. Let me warn you, likewise, that the Vapours which arise from boiling Oil are sometimes of a watery nature, which being collected in the neck of the Glass, and trickling down again in form of drops of Water, would occasion the same misfortune; for Lead in fusion is vastly impatient of Water. A seventh Experiment let us make with Tin; of which I have here half an ounce, mixed with an ounce and a half of Oil of Olives, which, in the same manner as before, I set over the

the Fire. You see, now, the Tin runs like Water at the bottom of the Glass, and though I put it in, in Filings, it is collected into one Mass. You perceive, likewise, that it now begins to be dissolved and mixed with the Oil. But eighthly, and lastly, I have here a composition of Lead and Tin mixed together in equal proportion, whilst they were in fusion. Of this Mass I have taken half an ounce and poured upon it an ounce and a half of Oil of Olives. I keep it now upon the Fire, as before, till it boils. You see, then, the metalline Mass melts and runs a great deal before the Oil begins to boil, and sooner than either the Tin or Lead would have been melted alone. There are many more curious things of this nature, but I must proceed no farther upon this head, as I have been rather too prolix already.

Give me leave, however, just to mention a few things to you, that follow from what has been said, and are worth taking notice of. First, then, Oils are disposed to receive and retain a great deal of Fire in them before they thoroughly boil. Secondly, there is not any one known Fluid in Nature, to which more heat may be communicated, than to Oil; for all *Lixiviums* and Oil of Vitriol boil sooner, and grow less hot; Mercury, too, sooner in some measure, or perhaps equally. Thirdly, Oils may be urged with a prodigious force of Fire, before they will be dispersed into Vapours, and rise out of the Vessel in which they are contained. In the fourth place, Oils are capable of communicating their heat to the Vessels in which they are boiled; and hence, tho' you may boil Water in a leaden or a tin Vessel, yet you can't boil Oil in the same before they will melt. Fifthly, Oils communicate their heat to Metals that are put into them. Sixthly, it is not easy to give Oil a greater degree of heat than what it naturally acquires when it is made to boil. If any person has a mind to increase this collection of Fire in Oils, he must contrive some method to compress it in its Vessel, with a greater force than that of the common Atmosphere, and then, indeed, the heat will be augmented proportionably, as we took notice before in Water and Air. And hence we easily conceive, that if Oil, when in the deep recesses of the Earth it is compressed by a vastly increased Atmosphere, should happen there to meet with any great Fire, it might conceive an immense heat. And if then, whilst it was thus prodigiously hot, it should chance to have Water break in upon it, what Earthquakes might be hence produced? Without doubt vastly exceeding all imagination: May any thing now of this kind possibly happen in Mount *Ætna*, *Vesuvio*, *Hecla*, and other *Vulcano's*? Certainly, amongst other causes, this deserves some regard with the Philosophers. Seventhly, liquid Oils will not permit a greater heat to be communicated to the Vessels that contain them, than they actually have in themselves; and consequently will prevent Fire's melting any Vessel that requires more than 600 degrees of heat to effect it. And eighthly, and lastly, here again we observe, that the wise Author of Nature has set limits to Fire, that in Oil, a Matter vastly inflammable, it might not grow insuperably violent.

Corollaries
hence deducible.

But farther, in explaining the dissolving power of Oils, it is absolutely necessary we should add this consideration, that the expressed crude Oils of Vegetables always contain some Water. This is evidently seen in express'd Oil of Almonds, by boiling it in a Bolthead; for then the watery Vapour that arises, being stopp'd upon the Sides of the long neck, is there plainly collect-

Oils act by
their Water.

ed in form of drops; and these afterwards running down again into the boiling Oil, produce a pretty extraordinary motion, noise, and crackling within the Glass. Hence, with respect to this latent Water, Oils act differently upon their solvend Bodies, in different degrees of heat; and the cracklings likewise that are produced during the ebullition make some variation in the solution. And for this reason, when by boiling a good while the Water is expelled, the power of an oily *Menstruum* is considerably altered, nor dissolves Bodies in the same manner as a crude one.

And their
occult Acid.

But those Oils, likewise, besides a Water, generally contain some subtil Salt, for the most part a volatile, acid one, which in many of them almost discovers itself by its Smell, and is of an exceeding penetrating nature. These Salts appear, and show themselves in form of acid Spirits, which collect themselves together like Water, separate from the Oil, nor will easily suffer themselves to be mixed with it again. It is not so easy, however, to disengage this Acid from its Oil; for if you take the native Oil that spontaneously oozes out of the Firr, Larch-Tree, or Pine, and gradually melt it over the Fire, then, from the beginning to the end, both in a small, and the greatest degree of heat, this acid Spirit will be separated from it; though at the beginning, indeed, with more ease, and in greater quantity. And the same thing holds pretty nearly, more or less, in the others.

And by both
together.

Whenever, therefore, the Chemist would accurately determine the dissolving power of these Oils, he must always first carefully consider, whether the effect performed by the Oil was not owing rather to the Water, or the Acid, than to the proper Oil itself; for otherwise we may be liable to run into very great errors. The Painters inform us, that those Paints that are dissolved in boiled Oil, are much readier taken in than those that are mixed with crude, and that the Paintings with the former dry pretty soon, whereas, those Colours that are mixed with crude Oil, lose more of their native beauty, and are a great while a drying. And in the same manner, that particular power, which the softest Oils are said to have, of dissolving Metals in a gentle heat, seems as if it ought chiefly to be ascribed to their latent Acid, and by no means to their true oily part. Thus, for example, if you mix the soft Oil of Olives, with a very fine powder of Iron, Brass, or Lead, and then digest them together for a good while in a gentle heat, part of the Metal will be dissolved and mixed with the Oil, will give it a colour, and often impregnate it with some remarkable virtue. But to suppose this to be the real dissolving power of Oil, as Oil, is to extend it beyond its proper limits; for when, by a continued ebullition, it is thoroughly freed from this adhering Acid, it then retains this power no longer. And thus the Polishers of Brass and Iron have long observed, that if these Metals, when they are polished, are exposed to the Air, they can't be kept from contracting Mould and Rust, by only rubbing them with crude Oil, though they may be very well secured by boil'd, especially if there is a little Ceruss, or Lead Ore, boil'd in it, by which all its acidity is absorb'd, and it is excellently well fitted to defend the beauty of such Bodies. And that there is in distilled Oils the same Acid the egregious *Hoffman* has demonstrated by an elegant Example, in his valuable *Physico-Chemical Observations*. p. 56. 57. Where, by rubbing distilled Oil of Lavender-flowers, and distilled Oil of Turpentine, with Salt of Tartar, he observes a
neutral

neutral Salt to be hence produced, arising from this Alkali, and an Acid drawn out of the Oils. And lastly, even a gentle distillation of these Oils, will extract some Salt from them; as we see in Oil of Turpentine and Juniper, which being treated in this manner, yield something of an Acid.

And as for Oil distill'd from alcalescent, or putrefied Vegetables, or the parts of any Animal whatever, this abounds so plentifully with volatile alkaline Salts, that these are separated from them, in large quantities, by a gentle Fire, and appear in solid little Glebes, as white as Snow. If you would attempt therefore to explain the proper virtues of Oils, you must first carefully free them from all their Salts, and then, by examining them when they are pure, you may be able to judge of their virtues without danger of mistake.

A volatile
Alkali often
in them.

But before we treat of Oils as *Menstruums*, it is still much more necessary and useful, to consider how long Oils do actually continue Oils. And here there occur many surprizing *Phenomena*: For Oils, either prepared with Water *per Veficam*, or drawn with a dry Fire in a Retort, whether sweet-scented, or fetid, if they are cautiously distilled in a Retort to a dryness, the Vessels being kept accurately closed, they leave an Earth at the bottom, gradually lose their viscosity, and grow more subtil, fluid, and transparent. And if you repeat this operation to the fourteenth time, or oftner, you constantly have an Oil different from the former, and every time some remainder, till at last you thus procure a penetrating anodyne Medicine, mighty efficacious in some grand diseases: But every repetition, likewise, you have a different *Menstruum*. And hence *Van Helmont*, the Father, in his *Aurora Medicinæ*, published in *Dutch*, p. 188, by a repeated distillation of human Blood with Spirit of Salt, till no *Fæces* remain, thinks he prepares a diaphoretic Medicine, which like a *Menstruum* dissolves all those preternatural viscidities in the human Body, which often give rise to fatal obstructions. The famous *Hoffman*, too, confirms the preparation of such a Medicine, and highly extols it for its virtues. *Obs. Phys. Chem.* p. 59. And another Author, tho' less indeed to be depended upon, was bold enough to assert, that in such an Oil as this you have a universal Medicine. But these things the Chemists of former ages have given us an account of. And indeed this is certain, that from Oils treated in this manner, such *Menstruums* are procured as have an excellent and scarcely imitable dissolving power. Upon this head, *Raimund Lully* and *Isaac Hollandus* have given us whole processes, which are fully enough described, and deserve consulting.

Simple Oils

And lastly, every kind of these Oils contains farther something vastly subtil, and volatile, which resides in them, but still may be separated from them: This we treated of formerly, under the title of the *Spiritus Rectior*, or *Archæus*. This Spirit is active, odorous, sapid, the Son of Fire; and is the true cause of incredible effects. This being generated in the Oils, and held down, and retained in them, endues them with a singular virtue, very efficacious, and scarce to be found any where else: And hence, when it comes to be perfectly separated from them, it leaves them vastly less active, nor hardly any longer distinguishable from one another. And as from many of them it spontaneously exhales with a gentle heat, it soon mixes itself with the Air, and leaves them effete, and incapable of performing what they could before. Thus then I have said enough of Oils to enable us to come to a

And a *Spiritus Rectior*.

certainty about their effects, considered as simple and homogeneous. And, indeed, the dissolving power of pure Oils seems chiefly to consist in their being able to admit a prodigious heat into their substance, and communicate it to other Bodies.

What true
Oils dissolve.

In the first place, then, Oils will mix with Oils; most of them with all others. Some, indeed, there are, that will not mix so easily, as appears in the distillation of Turpentine and Amber, where the Oils that rise in different degrees of heat, are found to be different in weight, thickness, colour, and situation, nor suffer themselves to be readily mixed together. The rest mix very easily. Secondly, true resinous Bodies melt, and are then sufficiently dissolved in Oils. As, thirdly, are most sort of Gums, especially if they have any thing of Resin mixed with them. Fourthly, Oils that are thicken'd, or, as they are called, Balsams, Tears, and Colophonies, are all diluted in Oils. As, likewise, fifthly, Sulphurs themselves, whether found naturally in the Mines, or produced by Fire, and that both liquid and solid; for these all suffer themselves to be dissolved by Oil, even though they lie concealed in other Bodies. Thus Antimony, if it is reduced to Powder, sublimed into Flowers, and then boiled with Oil, will in a short time yield a thick, red Balsam of Antimony, arising only from the Sulphur of the Antimony, resolved in the Oil, whilst the reguline part remains unaffected, but deprived of its Sulphur. And the same thing holds true, likewise, in other semi-metals, that abound with Sulphur.

Of proper spirituous Menstruums, or Alcohol.

Alcohol
among the
secret Men-
struums.

Those Alchemists, who were reckoned among the Adepts, throughout all their Writings make mention of Spirit of Wine. And this, when it was reduced to the greatest subtlety, they made use of, in the preparation of all their other secret *Menstruums*. This is evident in the *Circulatum* of *Paracelsus*. And for this reason, the indefatigable *Weidenfeldius* was induced at last to believe, that these Adepts have plainly enough described all their *Arcana*, except their philosophical Spirit of Wine, which, was it once come to be known, every thing would be sufficiently clear. Whether this, however, be really the case, I have reason to doubt; and, indeed, it is easy to make it appear, that the Spirit of Wine, which these famous Authors describe by its proper marks, is the very same that we have at present. This its subtlety; volatility; the manner of its preparation; its fragrance; the streaks that run down in its distillation; its burning away without any Water remaining; the burning of a Cloth wetted with that Spirit; its union with Salt of Tartar; its adunation into the *Offa Helmontiana*; the extraction of the subtil Sulphur of Animals, Vegetables, and Fossils with it; and lastly, its balsamic property of preserving Bodies, and securing them from putrefaction, abundantly demonstrate. Besides these properties, however, that we find in our Alcohol, these great men, I confess, ascribe other vertues to it, which at present we are not able to discover, as in particular its power of dissolving Salts: But then it still remains a doubt, whether this difference arises from our not knowing the proper Spirit, or from our not knowing some secret, but necessary method of preparing these Salts. Let this, however, be as it will, it is certain, there is often in those things something very surprizing. Some of the top Masters in Chemistry have publicly declared

clared in their Writings, that it is not possible to unite Alcohol with a pure fixed Salt; and no wonder: For if the least moisture conceivable has infected either the Alcohol, or the Salt, they can never be perfectly combined together: But when pure Alcohol, and perfectly dry Salt of Tartar are mixed together, a saturated tincture is soon extracted, and there is a true combination of the Alcohol and Tartar. For these Reasons, then, we can't sufficiently inquire into the nature of this Liquor, to which, on account of its excellence, we give the first place among spirituous *Menstruums*. This Alcohol, then, is obtained from nothing but Vegetables; and from them, only by Fermentation and Distillation. The best is prepared from Wine, *Hydromel*, and Malt Liquor. These Liquors themselves, if they are thrown upon Fire, put it out; and yet the Fluids that first rise from them in distillation, which are somewhat pinguious, limpid, sapid, and odorous, and are then called Spirits, upon the application of Fire to them, burst into a Flame, and burn away, tho' they are still very readily mixed with Water. And when afterwards by proper methods the Water is intirely separated from them, they then become true Alcohol, which we described before, when we treated of the *Pabulum* of Fire, p. 187, & seq. Hence Alcohol, upon every account, seems to be an exceeding subtil vegetable Oil, which, whilst it was thicker, consisted of Particles, which strongly attracted one another, collected themselves into drops, repell'd Water, and refused to be mixed with it, but being converted into Alcohol, have lost a good deal both of their attractive and repulsive power. Hence Oil comes to be called Alcohol, when it will mix with Water, and at the same time will totally burn. The Oils of Animals and Vegetables, likewise, may be altered and attenuated, in such a manner, by a perfect putrefaction, as to become so subtil and volatile, as to take Fire, whilst they are dispersed in the Air. Nay, and by repeated distillation, those Oils, in particular, come to be so exceeding fine, that they will bear in some measure to be diluted with Water, though not so readily as the former Spirits. Before, now, we can pretend to give any account of the dissolving power of these Spirits, we must first determine what this Spirit is: For the common Spirit of Wine, we know, consists of a good deal of Water, a liquid, volatile, acid Salt, a disagreeable Oil, and Alcohol: Rectified Spirit of Wine contains less Water, the same volatile acid Spirit as before, less of the nauseous Oil, and more Alcohol: Perfect Alcohol, prepared by itself, is composed of Alcohol, and something still of a liquid Acid: This Alcohol, once drawn off gently by distillation, from a fixed alcalious Salt, becomes perfectly pure. No body, therefore, concerning these things, should pronounce too rashly.

May be united with a fixed Salt.

1. Pure Alcohol dissolves Water, and is dissolved by it; as likewise all aqueous Fluids. 2. And hence all Wines, of what sort soever. 3. All spirituous, fermented Acids; of which kind are all sorts of Vinegars. 4. All pure Oils. 5. All true vegetable Resins. 6. Gum-Resins for the most part. 7. Pure volatile alkaline Salts. 8. Fixed alkaline ones, when they are perfectly dry. 9. Most *Sapo's*. 10. Sulphurs, dissolved and opened in alcalious Salts.

What Bodies it dissolves.

But native, compound Salts it does not affect, as Sea Salt, Nitre, and *Sal-Ammoniac*; nor pure Earth; nor Sulphur; nor Mercury, Metals, Semi-metals, Gemms, or Stones.

What not.

Of

Of the Menstruums called Spirituous, both Alcaline and Acid.

Chemical
Spirits an
ambiguous
term.

A great many of the Chemists have referred two sorts of *Menstruums* to the oily and spirituous ones, which ought rather to be placed amongst the saline, or the compound. And this happened, because they almost always had some appearance of oiliness, and at the same time were generally found to be volatile, liquid, and very subtil. Under this name of Spirits, therefore, went some Alkali's and some Acids, as they both appeared volatile, subtil, and subpinguious, tho' they were still, in reality, as different as almost any two things whatever. Nay, and even among the particulars of each kind too, there is observ'd a very great diversity. Let saline spirituous *Menstruums*, therefore, be divided first into Alcaline and Acid; for this distinction is absolutely necessary. Then let the alkaline spirituous be distinguished from another, as some of these are of a compound nature, others of a simple one. The most simple of these consist of Water, and a very subtil volatile alkaline Salt, which together compose a kind of limpid, thin, subpinguious Liquor; of this kind is the pure alkaline spirit of *Sal-Ammoniac*. And to this head belong an infinite number of others, produced both from Animals and Vegetables, when they are perfectly freed from all their Oil; for these may be prepared by Distillation from the hot antiscorbutic Plants, from every putrified Plant, and from every part of the animal Body, and are every where to be met with among the curious Chemists. But those, now, which are more compound, consist chiefly of Water, a Salt, which we shall by and by describe, and a fetid Oil; and they may be resolved into these Principles. These appear to be of a more pinguious nature than the former. These last Spirits, therefore, as they are called, are composed of a volatile alkaline *Sapo*, diluted in such a quantity of Water or Phlegm, that it is not capable of dissolving any more. And as for those Spirits, which for the most part are volatile acid Liquors, these likewise among the Chemists have obtained the name of Spirits, because these, in the same manner, are volatile and subtil, and in Distillation produce, as they run down, a kind of pinguious *Striæ*. All these, however, upon Examination, appear to be acid Salts diluted in pure Water; for even Oil of Vitriol itself, which is considerably fixed in the Fire, will, if it is distilled some number of times with boiling Water, become great part of it volatile. And the case is the same with Oil of Sulphur *per Campanam*.

A great many of these belong to Salts.

Upon these considerations, therefore, I think it will be much the properest method, to separate these abovementioned from the spirituous *Menstruums*, and place them among the saline, which is what I shall now proceed to.

Of the simpler saline Menstruums.

Salts necessary to be known.

Whoever is not acquainted with the tastes of Salts, will never arrive at the knowledge of our *Arcana*, is a maxim amongst the Alchemists: And no wonder, as a great many Salts are vastly efficacious in the Solutions of Bodies. And if we can put any confidence in the greatest Masters of the Art, that famous Solvent the *Circulatum* of *Paracelsus*, was made from Salt. This, however, is past all dispute, that in the class of *Menstruums*, Salts obtain every where the principal place. For this reason, I have for a long time taken a great deal of pains in these things, to see if I cou'dn't discover in them what was cer-

tain

tain and useful; that I might at last reduce this Doctrine, - often exceedingly confused, into some kind of order, and then candidly communicate it to you.

By Salt, therefore, we mean a Body that may be diluted in Water; that may be melted in the Fire if it does not first fly off; and that affects the Tongue with that sensation which we call Taste. What Salt is.

When this, now, is either artificially, or naturally perfectly pure, and without Mixture, it appears to consist of Globules so minute, that its single Particles are not capable of being distinguished by the most accurate Microscopes; and consequently, even these will give us no light at all into their figure. Nay, farther, when these saline Bodies are resolved into their pristine ultimate Elements, from whence they were concreted, they then seem to become perfectly volatile, and when they are separated from one another, and freed from every thing else, disperse themselves about, and mix with the Air. This we saw sufficiently plain from Experiments, whilst we were treating of Earth, p. 369, &c. When these ultimate Elements, therefore, of pure Salt, are so concreted into Masses, as to offer themselves to the examination of our Senses, they then always have something else intermixed with them, which serves as a *Vinculum*, to bind and hold these volatile Particles together; and this in particular is Water, and Earth, which are capable of keeping them thus in union for a long time, and forming them into such large Corpuscles. Hence, therefore, we very evidently perceive, that as the first Elements of Salts can scarcely ever be confined in Vessels, so very little can be asserted concerning their chemical, or other virtues. In the mean time, however, when they come to appear in a durable form, then, as compound Bodies, we may be able to come at some certainty about them. The Elements of these insensible.

In order to this, then, let us examine into the principal difference that is observed among them. And this I think in the first place, ought chiefly to be ascribed to the real difference that there is in their constituent Elements: For tho' we can't come to examine these, when they are separate, and alone, yet without dispute, tho' all agree in their volatility, yet each sort has always some distinct and proper virtue. But secondly, this difference may arise from the diversity of the other Principle, which being united with the former pure Salt, composes the Salt that falls under our Observation; for what reason is there, that this, in various Salts, may not be of a different nature? All kinds of Salts, therefore, we distinguish into such as differ 1. In their saline Principle. 2. In their uniting *Basis*; or 3. In both together. And then in respect of this saline Principle, and this first Division, I reduce Salts, and consequently, saline *Menstruums*, conveniently enough into the following Classes. 1. Into fixed Alkali's. 2. Volatile Alkali's. 3. Native vegetable Acids. 4. Fermenting vegetable Acids. 5. Fermented vegetable Acids. 6. Vegetable Acids procured by Combustion. 7. Vegetable Acids procured by Distillation. 8. Native fossil Acids. 9. Fossil Acids by burning. 10. Fossil Acids by Distillation. 11. Native Salts, called neutral ones, as Borax, Nitre, Fossil-Salt, *Sal-Gem*, Fountain-Salt, Sea-Salt, and *Sal Ammoniac*. 12. Other Salts that are compounded of these. All these Salts, therefore, must now be examined in order, that we may ascribe to every one of them its proper and peculiar virtues, and by this means come to a true knowledge of them, as they may be made use Kinds of Salts.

use of in the Solution of Bodies. To begin then in the first place with the fixed Alkali.

Of a fixed Alkali, as a Menstruum.

A fixed Alkali.

The word *Kali*, made use of upon the *Eastern* coast, and in *Egypt*, signifies a certain Herb, abounding in Salt, that grows about the sea-shore, and the banks of the *Nile*, and on those too of that famous River *Belus* in *Syria*, as *Pliny* assures us from ancient Authors. This Plant, if it is burnt in an open Fire, when it is come to maturity, produces Ashes that are remarkable for their salt acrid taste, and thus evidently demonstrate how full they are of Salt. If these Ashes are boiled in Water, they yield a strong, acrid, salt *Lixivium*, consisting of the Salt that is drawn out of them into the Water, which being properly poured off, there remains at the bottom of the Vessel another greyish part, which will not dissolve in the Water, nor will burn in the Fire, but is perfectly insipid, and of an earthy nature. If this *Lixivium* then is evaporated to a driness in an iron Kettle, there is left behind a white solid Mass, of a most acrid caustic taste, and perfectly soluble in Water. Since, therefore, *Lix* in the *Latin* Tongue signifies Ashes, and *Lixa* a maker of Ashes, hence *Pliny* very properly says, *Cinerum Lixivium*, L. xxxix. C. 99. And, *Lixivium Cinis*, L. xiv. C. 2. 25. L. xv. C. 18. But *Columella* calls a *Lixivium*, the Water when it is impregnated with this Salt, and filtered. L. xii. C. 41. All these Salts, therefore, for the future, may very conveniently be called *Lixivious* Salts. By terms, however, received into the Art, they are called an Alkali, alcalious, or alkaline Salts. Some likewise call them *Soda* or *Zoda*. From this Salt, and the *Calx* of all Stones that strike Fire with Steel, may be prepared a *Frit* for the making of Glass. For Soaps, they use the same made sharper with quick Lime, and any oily Substances whatever. The best of this sort of Salt, comes to us at present from *Alexandria* in *Egypt*, and *Tripoli*. As all our Physical knowledge, now, arises originally from what our Senses discover in natural Bodies, hence all the distinctions of them must be taken only from such sensible signs: Nor can we distinguish Bodies in any other manner. I now, therefore, proceed to lay down the following Characters of an Alkali, which I think are abundantly sufficient, both for the Chemist, and the Philosopher.

Its Marks.

1. This Alkali, therefore, owes its origin to a vegetable Substance. 2. It is only procured thence by the action of such a Fire, as by burning converts it into Ashes. 3. When it is prepared in this manner, it is always of such a nature, that it will remain a considerable time in the Fire, and thus demonstrate its fixity. 4. In a moist Air, it perfectly melts away and deposits some *Fæces*, being absolutely impatient of long dryness, tho' it is carefully enough preserved in any close Vessel whatever. 5. If you taste it, it impresses a Savour upon the Tongue, joined with a Sense of Acrimony, and that a caustic one; and it excites at the same time a Taste of Urine, on which account these Salts have, tho' not so properly, been called urinous Salts. For the proper Taste of this Salt does not resemble that of Urine, as the first application plainly demonstrates: But when this has been in the Mouth some time, and by its Acrimony has drawn out the *Saliva*, then the neutral animal Salts which are in the *Saliva*, by the power of the fixed Alkali, are deprived of all their acid,

acid, and thus become volatile and alkaline, and then impress upon the Tongue a disagreeable urinous Taste, of which this is the true origin. 6. This Salt, when it is perfectly pure and unmixed, has not the least smell of any kind, being exceedingly fixed in the Fire itself: But as it is vastly greedy of every Acid, if it meets with any Body in which there is a volatile alkaline Salt retained by an Acid, and concealed without any Smell, it then immediately absorbs the Acid, and the latent Alkali being by this means set at liberty and rendered volatile, disperses about an alkaline Smell, which is then falsely ascribed to the fixed Salt. This appears evidently upon throwing a fixed alkaline Salt into warm fresh Urine, upon which the Liquor, that was inodorous before, instantly emits a disagreeable alcalious Smell. 7. Another property of this Salt is, that if it is mixed with any Acid whatever, it presently produces an Ebullition and Effervescence; and afterwards is so intimately united with it into one Mass, that if the Saturation is compleat, the compound, so long as it continues so, discovers no sign, either of an Alkali or an Acid, but there is always by this means produced a third Salt, which the Artists now o'days chuse to call a neutral one. 8. If a pure fixed Alkali is mixed with the Juice of the Turnsole, Roses, or Violets, it presently changes their natural Colour, which is a kind of Purple, into a Green. 9. When the same is applied for some time to a warm human Body, and consequently one that exhales some Moisture, it excites an acute Inflammation, attended with all its Symptoms, which soon turns to a grey, hard, dead, and often black Escar, and therefore is capable of producing at last a true Mortification. 10. All these Salts have a power of deterging and getting out spots; which is never found to be the case in those called neutral. These then are the Marks by which these Salts may be known and distinguished from all others; and by these we shall be able to avoid any confusion in this History of *Menstruums*.

Such alkaline fixed Salts may be procured likewise from any crude, fresh Vegetable, burnt to Ashes, and treated in the same manner as we mentioned of the *Kali*. Out of some Plants, however, by this management, you can get but very little: Of this kind are those, which when they are crude, have such a pungent Smell, as stings the Nose, and makes the Eyes water; for almost all the Salt of these Plants is volatile, and is dissipated, and flies off with the Heat of the Fire. Garlic, the bulbous vomiting Roots, Onions, Scurvygrasses, Ladies-smock, Rocketts, Hedge-mustard, Cresses, Radishes, Rapes, Squills, Leeks, Mustard, and the like, I refer hither; in which nature has so far perfected their alcalious Salts, as to render them volatile, as in Animals.

These *lixivious* acrid Salts, now, have been known to the ancients in almost all ages. *Aristotle* tells us, *Meteor* II. C. 3. that the Ashes of burnt Reeds, and Bulrushes, boiled in Water, yield a plentiful Salt. And *Varro de R. R.* L. i. C. 7. informs us, that some of the Inhabitants upon the *Rhine*, having neither Fossil nor Sea-Salt, instead of them, made use of a salt Coal, which they procured from some sorts of Wood: From which it is pretty plain that they knew, according to *Tachenius's* method, to prepare these Salts in such a manner, as to make them less acrid, and to come nearer to the nature of the native neutral ones. Hence *Pliny* asserts, L. xviii. C. 28. that Ashes themselves have the qualities of a Salt, but are milder. And L. xiv. C. 26. that the burnt *Fæces* of Wine have the vertue of Nitre. And L. xvi. C. 11. he

L 11.

speaks

Its origin.

Well known
to the An-
cients.

speaks of the nitrous Ashes of burnt Oak. Nay, and they made use of it in Physic too, as we learn likewise from the same Author, L. xxxvi. C. 69, where he says, Ashes, when they are drank, have medicinal vertues. All these authorities, then, to which more might be added, if necessary, sufficiently evince, that the knowledge of Alkali's is not to be look'd upon to be so modern as some Persons imagine.

Prepared by
Fire only.

As far, now, as ever I have been able to inform myself, there was never yet discovered one native Salt with which the preceding Marks wou'd agree, all these alkaline Salts being procured from vegetable Substances by the action of Fire alone. But from the first time that ever Vegetables came to be burnt in the world, these Salts have been always produced, provided the Vegetables were reduced to Ashes. Hence, therefore, in all ages and places where this has happened, there must have been a prodigious quantity of this Salt generated, which always at last with the Ashes sinks down to the Earth. In the revolution, therefore, of such a vast number of years, this Salt, one should think, must have possessed great part of the Earth, and discovered its proper Nature, as we see the mountains of Salt do in the Island *Ormuz*.

Perish again.

But as this, now, is found by no means to be the case, nothing can be more certain, than that the Salts of burnt Vegetables, when they insinuate themselves into the Earth, often, indeed, render it fruitful, but in the mean time, soon lose their alkaline nature, put on the form of a new Salt, and then continue to act in that character.

Not in
Plants na-
turally.

And upon this head, we ought particularly to consider, that no Plant that ever grew upon the Earth, if it was suffered by time to grow dry and carious, wou'd ever yield one grain of a fixed Alkali: But on the contrary, they have been always found either to have been dissipated into such minute volatile Particles, as escape the Observation of our Senses, or else to have left behind them a certain Matter, which upon examination appear to be mere Earth. This universal Experiment, therefore, confirmed in all ages, evidently demonstrates, that Nature, whether you regard their Fluids or Solids, has never intermixed a fixed Alkali in the Composition of Vegetables. Hence, therefore, we assert again, that fixed alcalious Salts are produced by the action of the Fire, and not by any natural vegetating Operation. But this is still farther evinced by the following Experiment, which constantly succeeds in the same manner. Take any of those Vegetables, which if they were burnt wou'd yield a large quantity of a fixed Alkali; let these be brought to putrefaction according to art, so that their whole Substance shall be perfectly putrid; and they will by this means become exceeding fetid, and great part volatile; and if they are then burnt in an open Fire, won't yield one grain of fixed Salt, but will produce only some white, insipid, perfectly earthy Ashes; in which, if you expect to find any Salt, you'll be deceived. You, Gentlemen, therefore, who consider this Experiment in a proper manner, must be of my opinion, that fixed alkaline Salts of Vegetables, which are the only fixed alkaline Salts we at present know of, ought to be looked upon as absolutely the creatures of the Fire; and no doubt but you will think that they are as much so as Glass, which is made from the most lixivious Ashes, melted with the intensest Fire: But as no person living supposes that Glass is really procured from the Vegetable, when

it

it is thus put in fusion with a strong Fire, so certainly we must confess the case is the very same with this Alkali.

And hence, in the latter part of this Work, I shall demonstrate, that these alkaline Salts may be very easily resolved into a considerable part that is saline, hard, bitter, and almost vitrescent; into a simple Earth; and into an alkaline Salt, that is stronger and more pure: And thus we shall again see, that these Salts are by no means simple Bodies; but that they are compounded of different parts united together; and that this conjunction of these Principles into one Mass that appears so homogeneous, is owing intirely to the strength of the Fire. Hence, then, it will follow, that Nature never acts by fixed alkalious Salts, as by her proper Instruments, unless only when she receives them first prepared by the Fire: And that even in this case, when she makes use of them thus prepared in bringing about her designs, she then only operates by them, as they are compounded of the three abovementioned Principles; to which, however, as a fourth part, there still seems to remain somewhat of an Oil, as many Arguments induce one to believe.

Arises from different parts, united by the action of the Fire.

And hence again it appears, that as these fixed alkaline Salts are more and more disengaged by a separation of their constituent Principles, the Salt that arises hence will be continually different; for that which remains after a former separation, will always be of another and more simple nature, and consequently, will have a different power of acting. Take Pot-Ashes, for instance, which yield the best of this sort of Salt. A great part of these is a bitter, hard, pellucid Salt, that does not so readily dissolve in Water. Separate this carefully according to Art, and you will then be able to obtain a purer Alkali, which is fitter than the other, for a good many Operations that are perform'd by Alkali's, which will not succeed so well, if the former Salt remains mixt with the latter. And here we must carefully observe, that these alkaline Salts too, are often surprizingly changed by some other Body's falling in among them, whilst the Vegetables are burning, which being likewise of a fixed nature, may be united, and remain with them in the Ashes. Suppose, for instance, that some Nitre should happen to come among them; then this being fixed with the other vegetable Salt, would produce an Alkali, on which, if you poured Oil of Vitriol, it would emit a fetid Fume, that would smell of Spirit of Nitre; which never is the case, if the Alkali is pure. The same you easily conceive of Sea-Salt, and many others. And lastly, to render this Doctrine of Alkali's still more clear and compleat, we must take notice, that the very burning of the Vegetables, as it is performed in a different manner, will produce different Salts: For it is a known truth, that if the same Vegetable is burnt at once in a brisk strong Fire, it will yield another Salt from what it does, when it is slowly consumed by a smothering one, as we see in the Preparation of the Salt of *Tachenius*. But we must now proceed to give you an account of the principal alkalious Salts, which are made use of in the chemical Art.

Consequently various.

Among these, then, the commonest sort is that which is called *Potas*, or Pot-Ashes. This is brought yearly by the Merchant's Ships in great abundance from *Coerland*, *Russia*, and *Poland*. It is prepared there from the Wood of green Fir, Pine, Oak, and the like, of which they make large piles in proper Trenches, and burn them till they are reduced to Ashes. These being pre-

The Alkali of Pot-Ashes.

sently sifted, were by the Ancients called *Lix*; by the Moderns *Cineres Clavellati*, which name seems to come from the *Clavæ*, or Billets, into which the Wood is cleft, to make it burn more readily, whence *Clavula*, and then *Clavella* seem to be derived. These Ashes are then dissolved in boiling Water, and when the Liquor at top, which contains the Salt, is depurated by standing quiet, it is poured off clear, and makes the *Lixivium*. This, then, is immediately put into large copper Pots, and is there boiled for the space of three days, by which means they procure the Salt they call *Potas*, (which signifies Pot-Ashes) on account of its being thus made in Pots. This Salt, whilst it is hot and dry, must be put up in Casks, the Wood of which is dry, and has no Oil in it, and by this means it may be kept dry; otherwise, if it is exposed to the Air, especially a moistish one, it will run into a pinguious Liquid, which is very heavy, won't admit Air, is alcalious, and exactly like Oil of Tartar *per deliquium*: And by this very action, it deposites again fresh *Fæces*, and that in a very considerable quantity too; for I myself have, in this manner, got 6 drachms of these *Fæces* the first time from one pound. When this afterwards is dissolved by successively pouring hot Water upon it, and by standing is depurated from its *Fæces*, and the pure Liquor that is at top is accurately filtered, then, if it is inspissated to half the quantity by exhalation in a very clean glass Vessel, and afterwards suffered to stand quiet in a cold place, it will soon form upon the Glass little hard Glebes, of a regular figure, pellucid, that never dissolve even in a dampish Air, are diluted with difficulty in Water, are brittle like Glass, of an exceeding bitter Taste, and very much resemble that Salt, which in making Glass is thrown up to the top, and is called the Gall of Glass: This therefore is of a very particular nature: And by this method, one may obtain a great quantity of this Salt. But even in this way of preparing this Salt, you have again terrestrial *Fæces* to the quantity of 4 scruples in a pound: And thus at last you have the alkaline Salt in the remaining Liquor sufficiently pure. This, now, if it is inspissated quite to a dryness, produces a white alkaline fixed Salt, with which, and pure Sand, is made the finest sort of Glass. If this pure Salt now is exposed for a good while to a strong Fire, it will melt, and then always becomes more acrid, and being exposed to the Air in a glass Plate, will again dissolve and deposite *Fæces*. And if these Operations are repeated, as I mentioned before, in our History of Earth, the whole Salt will become volatile, and at last will be intirely resolved into an imperceptible exhaling part, and terrestrial *Fæces*: And thus again, both its Acrimony, and its dryness, will be destroy'd. But it often happens during the repetition of this Operation, that the Alkali changes its first nature, and is converted into a neutral Salt, which easily melts in the Fire like Wax: And hence some Chemists have vainly pleased themselves, that they were Masters of that great secret, an incrated fixed alkaline Salt, which the ancient Chemists so highly extolled. But this only happens from the volatile acid in the Air applying itself to this Salt, and being united with it, by which means a new kind of Salt is produced, compounded of this Alkali, and this Acid, and hence easily flowing in the Fire, but deprived of all its alkaline vertue. But otherwise, the fixed Alkali, procured in the manner we have described, has above all others, every mark which we laid down in defining an Alkaline. This Salt, therefore, we may fairly fix as a standard for all of this

kind, by the character of which we may examine any Salts that we are in doubt about, whether they belong to this Class, or no. And thus again is confirmed what we advanced before, that alcalious Salts, produced by burning, are made up of three Principles, and those very different ones too, *viz.* a pure Alkali, a bitter Salt, and a pure Earth. The true saline part here, now, is greatly less, than any one would imagine, and when it is alone, is volatile, escapes the notice of our senses, and hence, hitherto, we are not come to a knowledge of its proper nature.

The Juice pressed from Grapes that are ripe, spontaneously ferments; and during this operation it is properly called Must. After this fermentation is over, and its thicker *Fæces* are deposited, and it has stood quiet in the Pipe, it becomes liquid, fine, and homogeneous. This we call Wine; which has now deposited abundance of thick *Fæces*: These go by the name of the Lees, or the Mother, and were first dispersed through the Must, then work'd up into Flowers, and Yeast, and afterwards fell down, and were continually collected more and more at the bottom. The Wine, when it is thus become fine, if it is drawn off from the Lees into a clean Vessel, leaves all these thick *Fæces* behind it; from which, by pressing them strongly through thick, canvas Bags, they procure a turbid Wine, which they use for making the strongest Vinegar. The *Fæces* then that still remain in the Bags, dry, and formed into Cakes, if you burn them, will be consumed into Ashes. These, if they are sifted, dissolved in Water, and depurated from the subsiding Earth, yield a clear *Lixivium*. And this, lastly, by inspissation, in great Pots, produces a Salt, very like the former, but purer, and more acrid. This, then, is a second sort of Pot-ashes, which by the preceding fermentation seems to be rendered more subtil than the former. And this is a second general method of procuring an Alkali from every sort of Wine whatever.

An Alkali
from the
Lees of
Wine.

If the Wine, now, after it is fin'd and drawn off as above into a clean Pipe, stands a good while after it is thus perfectly fermented, and fine, there will then begin to appear little shining Bodies in it, like little Particles of Glass, which gradually uniting together into larger Globules, disperse themselves equally round the Vessel, fix themselves upon every part of it that the Wine reaches to, and thus by degrees incrustate over its whole Surface with a kind of stony Matter, called, for this reason, very properly, by the *Germans*, Wine-stone; by the Chemists, Tartar. This is always of an acid taste, and produced only from Wine, when it has been fermented, and depurated. Betwixt this and the Lees, now, there is a great deal of difference; for this, in particular, hardens into the form of a Stone, that always continues liquid; this fixes to the upper, lower, and, in short, every part of the Vessel; that intirely falls to the bottom. This Tartar, now, according to the sort of Wine from which it is generated, is red, grey, white, more or less pure, and more or less acid. Acid, rough Wines yield a greater quantity of it; the softer and sweeter, a less. If this Salt is put into a clean glass Vessel, and with a sand heat very gradually and cautiously urged, it gives a *Spiritus Sylvestris*, that disperses itself about, and is not to be confined; then other Spirits but a little acid; afterwards pinguious and thicker; and last of all an Oil, that is the most penetrating of any we know of.

A fixed Al-
kali from
Wine.

When

Prepared by
simple distil-
lation.

When these, now, are all drawn off, there then remains a very black Mass at the bottom of the Retort, which is perfectly alkaline, and exceedingly acrid; and this is the only method that I am acquainted with of producing a fixed, alkaline, acrid, vegetable Alkali in a close Vessel; for all other vegetable substances whatever, being exposed to the strongest distillation in a Retort, produce, indeed, a black Coal, but never, to my knowledge, afford an alkaline Salt, till this Coal is afterwards burnt in an open Fire. But if you then take out this black, alkaline, tartareous Coal, and burn it, you will have a white, alkaline Salt, the most acrid and purest of all the fixed Alkali's. By this surprizing Experiment, then, we evidently see, how much fermentation promotes the production of an Alkali, though at the same time it always heightens, nay, and seems almost to generate an Acid. Both Alkali's and Acids, therefore, are more readily produced by the assistance of fermentation, than without it; which observation, certainly, is of very great consequence, though you will scarcely find it taken notice of.

All Alkali's, however, from whatever vegetable, or in what manner soever produced, when by the strongest Fire they are at last brought to their greatest alkaline perfection, become so perfectly of the same nature, that they can scarcely be distinguished from one another. There is one, indeed, but a very trifling circumstance, wherein they differ, observed in making Glass, and that is, that Glass made with the very same Flints, but different, fixed Alkali's, shall often have some diversity in their colour, so that that which is prepar'd with the Alkali of Flints, shall be different from that made with any other. But it is very well known, how small a matter will make a very considerable alteration in the colour of Glass; as even pounding the Salt in a metal or marble Mortar, will produce a difference. Hence I have sometimes been ready to doubt, whether some metalline Matter might not possibly insinuate itself into Vegetables, and being naturally fixed in the Fire, leave something in their fixed Salt, that might afterwards discover itself in the Glass. Iron, it is certain, insinuates itself into many Bodies; and, perhaps, it may not be so intirely repugnant to the nature of Copper to do the same.

A fixed Al-
kali from
Nitre.

But the Chemists have discovered another particular method of producing a true fixed Alkali, which we have accurately described by *Glauber*, as follows. Take some pure Nitre in a clean Vessel, flux it till it runs like Water; and it will then scarcely have any visible motion. When it is in this condition, throw a little bit of live Coal into it, and in an instant it will produce a great noise, run about upon the Surface of the Nitre, consume, and then the Nitre will flow quietly again, as before. When every thing is still, throw a bit more in, and you will have the very same *Phænomena*. Repeat this Operation till the Nitre makes no more noise, or is set on Fire by the Coal, and then all that remains will, in every sensible, physical, and chemical property, be a fixed, alkaline Salt; for it has a caustic acrimony; it causes a urinous taste in the Mouth; it raises an ebullition with all known Acids; if it is saturated with Acids, it is converted into a compound Salt, whose nature is determined by the Acid it is mixed with; it has the same effect in changing of Colours, with the preceding Alkali's; the very same precipitations are likewise produced by it; and in the solution of certain Bodies, it discovers

discovers a perfectly similar, not to say the very same efficacy. In this Salt, however, there is yet constantly observed some difference from the former, as it always retains something of Nitre that is not perfectly changed from its pristine Nature. This, indeed, don't commonly discover itself till you pour some of the best Oil of Vitriol upon it; but then there immediately rises a Vapour, which by its smell of Spirit of Nitre, or *Aqua Fortis*, demonstrates, that there is still something remaining in the alkaline Mass, which, by the action of the Oil of Vitriol, rises from the Nitre itself. Nay, and even the Oil of Vitriol, too, generally grows black when it is mixed with *Glauber's* Alkali, whence it appears, that there is still left likewise some of the Coal, which was thrown in and consumed. *Glauber*, therefore, was certainly in the right, in believing this Alkali of Nitre to be in some measure different from other vegetable Alkali's; but when he extols its virtues so highly above all others, it's possible he was a little too fond of his own discovery.

But a third, and the most expeditious way of producing Alkali's in a short time, and great quantity, is as follows. Take of the best and driest Tartar, and Nitre reduced to a fine powder, an equal quantity, mix them together, and throw them, a little at a time, into a clean iron Ladle, made almost red hot, and there will be excited, as we shew'd you before, a momentaneous deflagration, and there will be immediately produced a white, alkaline, fixed Salt. This, too, is like a vegetable Alkali in every mark; but still it has the same peculiarity as the former. For here if you go to make vitriolated Tartar from it, there immediately arises a smell of *Aqua Fortis*, and the Matter turns blackish; a certain sign that there is something of Nitre remaining, in this case, as well as the former. See the egregious *Hoffman. Observ. Phys. Chem.* p. 241.

The same
from Tartar
and Nitre.

And lastly, there is another, and a pretty singular manner, too, of preparing a fixed, igneous Alkali, in a moment, almost, from Nitre, and is as follows. After the Sulphur is separated from Antimony, almost as clear as is possible, there remains the pure metalline part, which is called *Regulus*. Take this shining Substance, put it into a clean Crucible, melt it in the Fire, and when it is perfectly in fusion, add an eighth part of the purest, driest Nitre. You'll then be surprized to find, that this Nitre, which used to flow so easily in a strong Fire, cannot now be brought to flux, without the application of such an intense Heat, as is necessary for the fusing of Copper. But you'll here perceive, likewise, something more extraordinary, and that is, that when it is urged with such a degree of Fire as will melt it, it immediately acquires a golden colour, and when the whole is poured out into a melting Cone, it rises to the top, and appears like a golden Cake. This, now, if it is separated by striking the Cone, is vastly impatient of driness, and is of so acrid, alkaline a nature, that it is perfectly igneous in almost every effect: Nor has the greatest Masters in the Art ever found out any method by which one may communicate to Salt so great a degree of Acrimony. And here we may observe, that Nitre, which is the coldest of all Salts, and has not the least mark of any Alkali in it, when it is thus fused with the metalline part of Antimony, acquires this Acrimony, purely, as it were, by contact. It is credible, now, in this case, that the Sulphur of the Antimony is, by this means very intimately united with the Nitre.

Lastly, by
contact with
Antimony.

Nitre ; for if you take the Salt, thus produced, whilst it is exceeding dry, and hot, and throw it into very pure Alcohol, this presently extracts a very red Tincture from it, whose caustic quality is so great, that it can scarcely be born. This sudden alteration, now, I have observed equally to happen, whether the *Regulus* is made with Iron, according to *Suchtenius's* method, or with Tartar and Nitre, in the common one. But this will not be effected so long as the external Sulphur adheres to it, the Experiment then only succeeding, when this part being separated, the remaining reguline part is perfectly fus'd with the Nitre. The quick change, now, that is here brought about, which we meet with no where else, is so much the more surprizing, as Nitre with Sulphur never becomes alcalious, but is converted into a bitter *Sal-Polychrest*. And what still makes it more extraordinary is, that Nitre, if it is kept a vast while in fusion by itself, will remain the same without any alteration. Nor will Nitre, as we mentioned before, produce an alkaline Salt with Antimony, so long as it retains its Sulphur ; though when that is removed, it will with the *Regulus* generate it by simple fusion. Hence, therefore, from the combination of Bodies together in a certain manner, we see what sudden and unknown effects may be produced, which it was not possible to have foreseen ; and hence again we infer how likely we are to fall into errors, if we proceed too hastily upon general Principles. But once more, we here observe farther, how easily Nitre grows alcalious through its whole substance, viz. as it were, by mere contact ; in as much as it is not mixed with the melted Antimony, but precisely flows at the top of it, being perfectly expelled from it. And lastly, we may take notice, that this Salt, which is fluxed by itself so very readily, in an instant, is so altered in its nature, that it becomes the most difficult to flux of any we are acquainted with. Thus then, Gentlemen, I have laid before you all I have been able to discover in any Authors, concerning the origin of fixed Alkali's, and the division of them into proper classes, founded upon it, to which I have likewise added some of their virtues.

The efficacy
of a fixed
Alkali.

The order of our subject leads us now to examine into all those physical operations which these Salts are observed to perform. And that I may do this the most to advantage, give me leave to take notice to you once more, that though from the vast number of Vegetables that are perpetually burning, Nature is constantly employed in generating fixed Alkali's ; yet, notwithstanding the infinite quantity that is thus produced, there is not the least appearance of them any where to be found in the Earth ; whence it follows, that these Salts must either perish, or be continually changed in their nature. In perfect fixed Alkali's, then, upon examination, the following properties appear to belong in common.

First attracts
Water.

1. They attract Water very powerfully, to a great distance, and from every known Body in which it resides. This is plain from ocular demonstration ; for when such an Alkali is taken out of a strong Fire, if it is suffered to remain in a very hot Air, just by the Fire, where we can by no other art discover the least sign of Water, it will even there grow moist, and dissolve : And if it is then put into a clean, dry, glass Vessel, and dried over the Fire, and the Vapour that exhales, is caught, and condensed in an Alembic, it will yield again the pure Water which the Alkali had drawn into it.

Other

Other Salts, now, if they had been moist before, would have been deprived of their Water in the very same place, where the dry Alkali attracted a moisture. These Alkali's, therefore, are true magnets to Water; this they dissolve, and unite with them; by this they are dissolved and strongly united with it; and hence, when they are once dissolved in Water, a Heat as great as that of boiling Water won't perfectly dry them again.

Take, for instance, Oil of Tartar *per Deliquium*, put a mercurial Thermometer into the Vessel with it, and expose it to a Heat of 214 degrees, and you will find the Salt will not be dried. Nay, if you have a mind to effect this, you must put it into a metal Vessel, and keep it continually stirring in a Heat of more than six hundred: Hence, we scarcely know any Body that parts with its Water with more difficulty. I had a mind, now, to inquire into the power by which an Alkali thus attracts Water, the quantity which it takes in, and the space through which this power is capable of exerting itself.

Retains it
very strongly.

To this purpose, then, I took an ounce of a fixed Alkali, exceeding pure and dry, and putting it in a clean glass Basin, exposed it to a dry Air, in a subterraneous place, that was every way inclosed, nor in the least disturbed by any Wind; and I found, in a little time, that the Water was attracted out of this still Air, to the broad surface of the Salt, and it continued to be so, till the Salt had drawn in near three ounces of Water, but being then thoroughly saturated, it did not imbibe any more. Hence, then, I learned evidently, that this quantity of Water, which was thus attracted to the surface of the Salt, required at least six cubic feet of Air to supply it: For if we suppose the weight of Air to be to that of Water, as 1 to 1000, and a cubic foot of Water to weigh 64 pounds, then all the heavy Bodies in a cubic foot of Air will weigh $\frac{8}{125}$ of a pound. Let us imagine, now, only half of these heavy Corpuscles to be pure Water, the other half, all the rest of the Bodies that are contained in the Air, and then it appears, that in a cubic foot of Air there will be about half an ounce of Water. If this Salt, therefore, is capable of attracting this Water from so great a space, we discover a new and very surprizing power in Nature. Hence *Sendivogius* said, very justly, the more Alkali's are burnt, the more Water these calcin'd Bodies attract out of the Air. If you are rather of opinion, however, that in this case the Water which is in the Air at a distance, comes into that Air which is nearest to the Salt, and so is exhausted of its Water, I will not contend with you; but this, in the mean time, I am certain of, that the Air, where the experiment was made, and from which the Water was separated, was exceeding still.

Draws it
from a great
distance.

But to come at the same thing still more exactly, I took a large glass Bottle, very clean, hot, and dry, and into this I put some pure Salt of Tartar, very hot and dry, likewise, and reduced to Powder in the manner above described. I then presently stoppt the Mouth of the Bottle with a dry Cork, and covered it over with a Hog's Bladder, well rubb'd with Oil, and made very supple, which I tied over it; and I afterwards found, that the Salt, which adhered to the side of the Glass, was grown moist with the Water contained in that small quantity of Air that was included with it, tho' the Air was hot and dry, at the time that the Bottle was closed.

And very
efficacious.

M m m

2. But

Secondly,
repels Air.

2. But with respect to Air, now, Alkali's seem to have a quite contrary power; for as they attract Water, so they seem to repel pure elastic elementary Air. Indeed one would be apt to think otherwise: For if a fix'd alkaline Salt, when it is perfectly red hot, nay, in fusion, is poured into an iron plate, it will soon attract some Water into it; and as this Water is drawn out of the Air, one would imagine, it should attract the Air along with it, especially, as it formerly appeared, that when Water is by any means deprived of its Air, it always spontaneously takes in more. Nay, and for this reason it would farther seem probable too, that the Salt should attract Air into it, viz. that all the Air that was in it before must have been expell'd by the intenseness of the Fire in which it was melted. On these accounts a person would be apt to infer, that a great deal of Air must be drawn into, and lie concealed in these Salts; and yet if you examine Oil of Tartar *per Deliquium* at the Air-pump, it does not give any indication of Air's coming out, nay, even though you make it hot. Hence, therefore, again every body would conclude, that these Alkali's do not only repel Air, but that they likewise even expel that which is lodged in the Water; and hence, that there is in these Salts a power of repelling Air, and driving it from among them.

Or, perhaps,
attract it ex-
ceeding
strongly.

But you may remember, Gentlemen, that whilst this point was before under examination, we brought it to this conclusion, that it was almost probable, that Alkali's attract Air into them exceeding strongly, and so closely unite it with them, that they do not let it go again, until it is forced from them, by a strong Fire, or being put into an effervescence. *Vide.* p. 303, 310. Upon a careful consideration, therefore, of these opposite appearances, I am in a doubt, whether, under this second property of Alkali's, I should conclude, that they perfectly repel Air; or that they unite it so intimately with them, that scarce any Body attracts it more strongly, or fixes it more closely. One of these two must certainly be the case; which of them is so, I dare not assert. Thus you see the extraordinary issue of so many Experiments, performed in a proper manner, viz. a fluctuation between two opinions, that are diametrically opposite to one another. This, however, is the nature of true Philosophy, nor can we any other ways come at a right knowledge of it. These uncertainties, in the mean time, have this evident advantage, that they put others upon farther inquiries.

Do not repel
Alcohol.

These pure, acrid, fixed Alkali's, if they are mixed with the choicest Alcohol, when they come first out of the Fire, attract it into them, and unite it with them; but if there is the least mixture of Water in it, then the Water is immediately attracted, and the Alcohol repelled; nor can they afterwards be united, by any method whatsoever. Nor can this union be effected, if the Alcohol is pure; but there is Water in the Salt. In this manner, therefore, pure Alkali's elegantly divide strong Spirit of Wine into two parts, that are not miscible with one another, viz. into a Water saturated with the Alkali, and into a pure Alcohol swimming at top. And thus, again, plainly appears the reciprocal attractive force betwixt the Water and the Alkali. For take a pint of the purest Alcohol, put into it but a very small quantity of Water, and then throw in such a dry, alkaline Salt, and the Alkali will in an instant draw into it that little portion of Water, upon which there will appear a kind

of

of tenacious Oil about the sides of the Glass, and at the same time, the combination of the Alcohol, and Water, will be perfectly prevented. Hence then we see evidently, how many, and what singular, physical operations may be performed by means of fixed Alkali's, when they act upon those Fluids that are prepared by fermentation, considering them as acting, either by an attraction or repulsion of the Alcohol, or by an attraction of the Water alone. Nay, and these Alkali's act upon these Liquors yet in another respect: For as every Spirit drawn by Fire from any sort of Wine has always a volatile Acid intermixed with it, hence the Acid being greedily attracted by the Alkali, the Spirit by this means becomes much more pure, as it is now freed from its inherent Acids, and consequently will be very different both in its nature and virtues, from what it was before this Operation. And the Alkali itself, likewise, will at the same time be intirely altered, will become a compound of an Acid and Alkali, and if it is perfectly saturated in this manner, will produce *Sennertus's Sal Purgans de Tartaro*. To this Observation, lastly, we are indebted for a preparation of pure Alcohol, without distillation, or any assistance of Fire: For mix only a sufficient quantity of Pot-ashes with common Spirit of Wine, and stir them about till they are thoroughly mixed together, and the Water will run into the Alkali, and the Alcohol will swim at top, which, by a gentle decantation, will come off good the first time. If you doubt, however, whether it is quite pure or no, only put some more Ashes into the Alcohol thus prepared, and by stirring them about, and then pouring the Liquor off, you may easily make it so. In this Operation, however, the Spirit of Wine always discovers a pinguious Oil, which before appeared neither in the Spirit of Wine, nor the Alkali, but is then only generated when they are thus mixed together.

In the fourth place, the power of these Alkali's manifests itself particularly upon distilled vegetable Oils. For if the most acrid, pure, dry Alkali is thrown very hot into a distilled Oil, it attracts it violently into itself, with a mighty hissing noise, and unites it so well with its Substance, that there is immediately produced a kind of Soap, which is still combined more closely, and brought to greater perfection by this mixture's being set in a subterraneous place; for by this means both of them become semi-volatile and form a Mass dissoluble in Water, which is endued with excellent medicinal virtues, and is the *Ens parvum Sapientum*, the *Sapo Helmontianus*, the *Sal-Volatile Tartari Starkeianum*, and the *Corrector Matthei*. This sort of Medicine was very famous, first in *England*, and afterwards all over *Europe*: For it powerfully softens and resolves almost every kind of viscid concretion that is generated from the humours of the human Body: Hence it incides and attenuates the *Saburra* that clogs up the Vessels, and at the same time it gently stimulates the Vessels themselves, and makes them act with a moderate *impetus*, and thus in both ways proves an aperient, and by Perspiration, Sweat, and Urine, carries off the Matter of the most stubborn chronical diseases. If it is digested too with simple Substances, it alters them, and quite changes their natural disposition, and by this means subdues the virulent efficacy of many of them, and imbues them with new virtues. Its medicinal power, however, as a universal medicine, which is the common fault of Chemists, has been too much extoll'd. But here let me caution you, that this combination can never

Attract distilled Oils.

be effected, if there is the least Water, either in the Alcohol or Oil, and consequently, never by cold Salts. Nor will it succeed, if but a small portion of the alkaline Salt stands above the Oil, and thus, by coming to the Air, grows ever so little moist.

And express'd ones.

Alkali's are easily united likewise with the express'd Oils of Vegetables, or even Animals, as is commonly seen in boiling them into artificial Soap by the assistance of quick Lime, Water, and Fire. And the Substance thus produced is wonderfully efficacious in a great many things, which wou'd otherwise be performed with a great deal of difficulty: But the chief of these are mention'd already under the former head.

And Acids likewise.

But alkaline Salts, in a particular manner, attract all kind of Acids whatever, whether produced in the Animal, Vegetable, or Fossil Kingdom, and that, whether dry or moist, pure or diluted. And this power of Alkali's, by which they thus attract Acids, is vastly greater than the same with respect to Water: For in this action, by which they unite these Acids with themselves, they violently expel the Air that resides in the Salts, whence arise such numbers of Air-bubbles, which suddenly appear, and then burst asunder. Nay, and by this very combination, they even repel Water itself from them pretty considerable; and when they are thus saturated, they will easily suffer themselves to be dried, or deprived of their Water, which before, when they were separated, they retained very tenaciously. Pure acid Oil of Vitriol, for instance, when it is alone, you can scarcely, by any Art, free from its Water; Oil of Tartar not without a great deal of difficulty: And yet when you mix them together, the Water is expelled in such a manner, that a Salt almost dry appears in the Vessel under it; as is evident in the Preparation of *Tartarus Vitriolatus*. The same is true of other Acids likewise, when they are combined with an Alkali: And from this consideration, many abstruse things in the Doctrine of *Menstruums* may be easily understood. But this Power, by which Alkali's thus attract Acids, is limited and confined within certain bounds; and hence there appears a vast diversity among them, tho' this, indeed, is more owing to a difference in the Acids than in the Alkali's. This affair, the knowledge of which is exceeding useful, the egregious *Homburg* has very happily explained, as indeed he has every thing else he has attempted, in the *Mem. de l'Ac. Roy. des Sc. T. I. p. 52*. A few of the Observations, therefore, which he has there given us, with your leave, I will here lay before you. One ounce of Salt of Tartar, absorbed all the Acid from 14 ounces of the best distilled Vinegar; and hence, after it was dried, it was increased in its weight 3 drachms, 36 grains; the remaining part of the Vinegar being mere insipid Water. By this means, then, we discover the proportion there is between the Acid, and the Water of the Vinegar. From Spirit of Salt, the same absorbed 2 ounces 5 drachms; and hence became 3 drachms, 14 grains heavier. From Spirit of Nitre, 1 ounce, 2 drachms, 36 grains; its weight being thereby increased 3 drachms, 10 grains. From *Aqua Fortis*, it took up 1 ounce, 2 drachms, 30 grains; gaining hence 3 drachms, 6 grains, in its weight. From Oil of Vitriol, 5 drachms; the increase of its weight, 3 drachms, 5 grains. As these, therefore, are the principal Acids, we may easily infer in the first place, that Acids, tho' very different in their specific Gravity, when they have saturated an Alkali, are observed to have the same weight; for Vinegar, which is the lightest Acid of

of all these, increased the weight of the same Salt of Tartar, as much as the Oil of Vitriol, which is the heaviest, and most pure: The same too is true of the rest, the difference between the greatest and least increase of weight, being no more than 31 grains, and that only in Vinegar, arising from the *Tartarus Regeneratus*'s being dried with a vast deal of difficulty. 2. Hence, therefore, Acids seem to differ chiefly in the quantity of Water they are diluted with, since the pure Acid, when it is extracted, discovers always the same weight. If 14 ounces, therefore, of the strongest Vinegar, cou'd by any contrivance be reduced into 5 drachms of Acid, by separating the Water from it, and collecting together the Acid without making any alteration in it, wou'd then this collected Acid be as strong as Oil of Vitriol? This is certain, it wou'd be then capable of saturating the same quantity of Alkali. 3. We hence see, Thirdly, how great a part of these Acids is Water; and that, therefore, it is probable, Fourthly, that if these acid Salts could be obtained pure without any Water at all, they would then appear in a solid form. This, however, has never yet been accomplished: Very intense Cold has come nearest it of any thing, but not quite completed it. Hence likewise we may conceive what surprizing effects alkaline *Menstruums* may produce, when they act upon Solvents that have any latent Acid in them; or upon those that are actually consolidated, and held together by an Acid, and hence when this Acid is absorbed, fall again into their constituent Elements. How great an Effervescence is by this means excited? What a production of light Bubbles, that presently mount up, and are continually bursting, and by this means cause a hissing noise, and generate a very elastic Air! But all these sudden effects cannot be understood without a right notion of the Doctrine of Alkali's. But I must here take notice, however, that when this affusion of an Acid to an Alkali is performed gradually and cautiously in warm Liquors, and in a large Vessel, and if at the same time the Vessel is shook after every instillation of the Acid; then you will come at last to that temperament in which there will be no farther Ebullition: And this is called the point of Saturation. If you afterwards proceed to pour on the Acid, there will be no more agitation excited, then there is upon mixing Water with Water: And then the Compound thus produced, is neither Alkali nor Acid, but a neutral one concentered of both, which acquires its name from the Acid that saturated the Alkali. Hence the Acids have been called Males, and the Alkali's Females, and the Compound of them both, Hermaphrodites: The Alkali, the *Vacuum*; the Acid, the *Implent*: The Alkali the *Chaos*, and the Acid the impregnating Spirit. This extraordinary Ebullition and Effervescence, now, that arises between the Alkali and the Acid from the violent expulse of the Air and Water, may be owing possibly to these Bodies impetuously driving out whatever lies between them, when they rush strongly into mutual contact: And then this wou'd not arise from any disagreement, but an association of Principles. Will you hence, therefore, be induced to believe, that Acids abound plentifully with Air, but that Alkali's are without it? Certainly, the strongest Alkali, taken very hot out of the Fire, and hence probably deprived of all its Air, will, if it is thrown into an Acid, produce a prodigious Effervescence. Is this the reason then, that Acids, when they are predominant in Animals, are so very flatulent? Do the Salts produced from a combination of Alkali's and Acids, lose the greatest part of their

Air, and are they hence found to be so little flatulent in the human Body? Are for the same reason, Acids alone, or at least acescent Bodies, disposed to ferment? And does there hence, in fermentation, arise such a tumultuous Air? Does fermentation hence naturally tend to the generation of Acids; Fire, when it burns openly to the production of Alkali's? And does hence Fermentation, the Parent of Acids, perform its work with a small degree of Heat, whilst a greater is necessary to dispose Animals by putrefaction to become alcalious? But to proceed: We farther observe then, that when these Salts are once perfectly saturated, they continue afterwards at rest, nor generate any new motion, tho' you persist in pouring upon them either Acids or Alkali's. Among the natural causes, therefore, by which motions are excited in the Universe that did not appear before, we must reckon Alkali's and Acids, at the time when these are mixed pure together, which cease again, as soon as ever this combination is compleat. Nor can we at all doubt, but that in the action of these alkaline *Menstruums* upon Acids, the Water is expelled out of them as well as the Air, when they thus unite together; for tho' they are perfectly fluid when they are mixed, yet they harden in the very act of combination into little saline Globules, and appear in the Water in the form of pellucid Chrystals, the watery Liquid being driven out, and swimming at top. Nay, and when the Saturation is quite perfect, the Water may be drawn away pure, and without any saline Taste, which being all separated, the remainder is converted into a white, mealy, opaque, dry Powder. These compound Salts too, are easily dried with a gentle Fire; whereas the simple Alkali's and Acids, by whose combination they are produced, either cannot be dried at all, or not without the greatest difficulty. And again, tho' these compound Salts thus prepared, part with their Water easily; yet it is vastly difficult, by the assistance of Fire alone, to separate either the alkaline or acid Salts, so as to procure them quite pure. If any one, for instance, has thus made a *Sal-Ammoniac*, from an alkaline Spirit of *Sal-Ammoniac*, and Spirit of Sea-Salt, he may, indeed, sublime it, by exposing it to the Fire, but he will not thus be able to separate it into the saline Principles of which it was compounded. The same likewise is true of *Tartarus Vitriolatus*, *Sal Marinus Regeneratus*, *Nitrum Resuscitatum*, *Tartarus Regeneratus*, and others. There are, however, some methods found out, by which one may obtain this resolution of compound Salts, into their constituent alkaline and acid saline Principles; and the knowledge of these will lead us into some of the most secret Arts of Chemistry. In order, therefore, to get a proper insight into those, let us proceed to examine some farther properties of Alkali's.

The attraction
of Acids
by Alkali's
various.

Alkali's, therefore, attract all known Acids; tho' at the same time we must take notice, that they attract some much more powerfully than others. This assertion is abundantly confirmed by Experiments. If to an Alkali perfectly saturated with Vinegar, or *Tartarus Regeneratus*, you pour Spirit of Nitre, or Sulphur, or Vitriol, then the latent Alkali will attract into it that Acid, and repel from it the acid of the Vinegar with which it was before saturated; and hence a Liquor, which will be nearly Spirit of Vinegar, may be afterwards drawn from this Compound with a moderate Heat, there remaining a considerably fixed, regenerated nitrous Salt at the bottom of the Vessel: and if you put to it Spirit of Salt, Sulphur, or Vitriol, the Alkali will in the same manner

ner attract them, and let go the Acid of the Vinegar. Again, if you take an Alkali rightly saturated with Spirit of Nitre, and mix it with Spirit of Sea-Salt, there will arise in distillation an *Aqua Regia*, and a nitrous Salt will be left at the bottom, but changed from its former nature. And if upon an Alkali perfectly saturated with Spirit of Salt so that it is become Salt, you pour Spirit of Nitre, the Compound, by distillation, will yield an *Aqua Regia* likewise, and the Salt that remains at the bottom will be of a nitrous kind, containing an inflammable matter that will make it deflagrate, but yet will be somewhat different in its nature, both from the Salt and the Nitre. In these two cases, therefore, as between the acid of the Nitre, and that of the Salt, there is no such great difference with respect to their acid quality, each of these Acids seems in some measure to have dislodged and driven out the other, by which means they both rise mixed together, and both of them likewise, with the Alkali for their *Basis*, help to make up the *residuum*. If you take an Alkali saturated with Spirit of Nitre, and pour upon it Oil of Vitriol, a pure Spirit of Nitre is immediately expelled, and the acid of the Vitriol continues united with the alkaline part of the Nitre, and makes a Salt at the bottom, which has in some measure the nature of *Tartarus Vitriolatus*, tho' it differs from it in some of its qualities; but it has scarcely any thing in common with Nitre. And lastly, if upon factitious or natural Sea-Salt, you pour Oil of Vitriol, there presently fumes up a very volatile acid Spirit of Sea-Salt, that possesses almost all the known virtues of it, except that it fumes more, is more volatile, and its Vapour is of a suffocating nature, till it is corrected by a repeated depuration. All these Experiments, therefore, certainly evince, that those Acids, which are naturally contained in a less quantity of Water, have a power of uniting themselves with Alkali's, superior to that of those, which are naturally diluted with a greater. And this Rule, as far as I know, holds true, and may be laid down universally, that stronger Acids always expel from their residence in Alkali's, those Acids which less powerfully adhere to them. And then, Secondly, these stronger Acids always unite themselves with that Alkali from which the weaker Acid was expelled, and take possession of the place in which that was seated before. Thirdly, the Salt thus regenerated, losing the disposition it had from the first Acid, which is now removed, puts on very nearly the nature of that Salt, from which was drawn the last Acid which is now united with the Alkaline part. In the Fourth place, however, it must be confessed, that betwixt the Salts thus produced, and those native Salts from which those Acids were drawn, there is always some pretty remarkable difference. Thus, for instance, the *Sal Mirabilis Glauberi*, which is prepared by distillation of Sea-Salt, with the best Oil of Vitriol, is of a very different nature from that which is obtained from Oil of Vitriol, and Oil of Tartar combined together into *Tartarus Vitriolatus*: Which is likewise observed in others. And again, the Salt which is procured by distilling Glauber's Spirit of Nitre, is quite another thing from his *Sal Mirabilis*, tho' both these are supposed to be produced from the same Acid and Alkali. This rule, therefore, which has been laid down by the most famous Chemists, *That Acids always convert Alkali's into their nature in such a manner, that from these Compounds may be constantly regenerated those Salts, which before yielded those Acids*, is too general, and must be understood with some restriction. In the Fifth place, I observe farther, that when these Acids thus poured upon

upon compound Salt, expel thence the Acids that were united with them before, and unite themselves with the remaining Alkali's, this new combination is effected without any considerable Effervescence: For the first Acid quits its place, and the last succeeds it without much conflict, notwithstanding there arises such a prodigious ebullition, when a pure Alkali is mixed with a pure Acid. Nor does it appear, that any Air is generated by this adunation, tho' in the other case it was expelled in so large a quantity. Does this happen, then, because the Effervescence that was excited in the preceding Saturation, had expelled all the Air, so that now the new Acid does nothing more than enter into the saturated Alkali thus deprived of its Air, and remains there without either expelling any Air, or attracting any? This certainly seems confirmed by this Observation, that if that second Acid is expelled by a stronger Acid, and is then mixed with another Alkali, it will with that raise as violent an Effervescence as the first did; so that in this Operation there shall be produced again the same Heat, Noise, and Air, whilst in the compound Salt there was scarcely any such appearance. Hence then we understand, the wonderful *Metempsychosis* and *Palingenesis* of these acid Salts: By these many philosophical arts may be invented and cultivated: By these, many unheard of changes may be brought about in natural Bodies, of which there are at present no instances, nor any known Instruments, and of which, consequently, no account can be given from any other principles which mankind has hitherto been acquainted with. These things, Gentlemen, it was absolutely necessary to lay clearly before you, whilst we had Alkali's under consideration as solvent *Menstruums*; for in the application of these to various Bodies, you will meet with an infinite number of *Phænomena*, which without the knowledge of this Doctrine, you could not possibly account for.

Problems
hence raised.

There are some other things, likewise, which occur upon this head, that one would be still farther induced to suspect, but which require, however, a more mature inquiry, before they can be admitted as certain: These, therefore, with your leave, I will here add by way of Problems? Do all fixed Alkali's owe their origin to Fire only, as their generating cause? Do all volatile Alkali's depend alone for their production, on a degree of Heat that is necessary to putrefaction? Is it possible in nature, that a fixed, or a volatile Alkali, if exposed to the open Air, can long continue an Alkali? Or will they, by every where meeting with an Acid, or an oily Substance, be converted into a neutral Salt, or a *Sapo*? Does not the same thing happen to them likewise in Vegetables, and in the Bodies of Animals? Is there not by this means continually produced a very large quantity of compound Salts, and of those in particular which will arise from an Alkali, and that Salt whose acid is every where distributed? As natural Acids, therefore, or those which are generated from Vegetables by Fermentation, are always, and every where present, does it not hence happen, that this compound Salt is most frequently of the nature of *Tartarus Regeneratus*, or of that of the *Spiritus Ophthalmicus Mindereri*, which arises from the combination of a pure volatile alkaline Salt, with distilled Spirit of Vinegar, which is not acrid, but vastly penetrating and active, tho' at the same time not endued with much Taste. But amongst all these things, there is nothing, that for very weighty reasons, deserves more to be examined into, than the origin and nature of those Salts, which on account of their commonness and use we are

are the most acquainted with of any, viz. Fountain-Salt, *Sal-Gem*, Sea-Salt, and Nitre. Concerning these, we would particularly inquire, whether they are produced by a combination of the Acid, into which they may be chemically resolved, with a fixed vegetable Alkali? Or whether, on the contrary, they are simple Bodies, just as nature has generated them, and by the action of the Fire are rather changed in their disposition, than separated into their proper constituent parts? The Chemists, certainly, especially after *Franciscus Trava-ginus* of *Venice*, and the famous *Otto Tachenius*, had published their Writings of Alkali's and Acids, have been of Opinion, that all these Salts were in reality originally compounded of an Alkali and an Acid that were before in being, and that they then first appeared in the Universe. After a good deal of consideration of this matter, however, it appears very probable to me, that the Salt in the Sea did actually exist before there was any the least sign of the acid Spirit of this Salt, or any fixed Alkali from burnt Vegetables to be found in the World. Nay, from Sea-Salt, no Mortal has been ever able by any Experiment whatever, to procure one Grain of a fixed Alkali. This, I myself, have sufficiently experienced. Take any quantity of the purest, driest Sea-Salt, and by long rubbing, mix it intimately with three times as much very dry common Bole: Urge it then in a very strong Fire in what manner you please, and it will yield but a certain proportion of acid Spirit of Salt; nor can you procure any more from it, tho' you increase your Fire to ever so great a degree. At the bottom of the Vessel, then, there will always remain the Bole, which will still continue Salt. Take this, and with Water wash out all the Salt, then filter it carefully, and form it into Chrystals; and what will you by this means be able to procure? For my own part, I can say, I never found any thing of an Alkali in it, but that it always still remained Sea-Salt. Besides, as far as I have been able to inform myself, no Person living has ever discovered any such thing as an acid Spirit of Nitre, or Sea-Salt, but what was produced by Art or Fire, from these pre-existent Salts: And when this is the case, it seems much rather to arise from a real change, than a proper separation of the concurrent parts. I confess, indeed, that these Acids, when they are poured upon alcalious Salts according to art, do produce regenerated Salts, which seem to come as near as possible to those Salts from which the Acids were drawn: But yet, still there is always some difference betwixt these regenerated Salts, and the native ones. These things, then, being rightly considered, make it plain, that we can't be so certain about the composition, and resolution of these Salts, as those Gentlemen wou'd persuade us. In the mean time, you observe, how cautiously we should look about us, when we make use of Alkali's in the solution of Bodies: For by the accession of something else to them, these Alkali's may be immediately changed into another Salt, and act no longer by that simple alkaline vertue, which it had when it was applied, but according to the disposition of the new Salt that is thus produced. But enough of this: Let us therefore proceed to something else.

In the seventh place, then, there is this very considerable in fix'd Alkali's, that when they are apply'd to certain Bodies that we wou'd have perfectly dissolved, they seem, indeed, at first to effect this, but are presently converted into Masses that are scarcely to be dissolved by any *Menstruums*, and which are in their

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nature

A fixed Al-
kali produces
Glaſs.

nature as far different from *Menstruums* as any thing can be. If, for instance, a hundred parts of pure Sand, or calcined Flints are reduced to a fine Powder like Flower, and then intimately mixed with a hundred and fifteen parts of a pure fixed alkaline Salt powdered likewise very fine; and this Mixture is then exposed to a moderate Fire in a Glass-house arch for the space of an hour, and kept constantly stirring, and afterwards, keeping it still continually stirring, to a stronger Fire for five hours more; you will by this means prepare a matter, which will have the dispositions necessary for making the choicest Glass. But if this, however, is then put up into a good dry Cask, and set in a dry warm place for four or more months, the combination of the Alkali and the Flints will be still farther perfected: If this Matter, then, thus prepared, is put into the Glass-house Pots, and exposed to the intense Heat of the Furnace, it will melt into a thick, tenacious, pinguious kind of a Liquid; and whilst it is boiling there, it will cast up a Scum to the Surface, which continually increasing more and more, rises often to a fourth part of the whole Mass. When this Scum now is carefully removed, till there appears no more of it, and the pure despumated Matter has been kept two or three days in fusion, what then remains in the Pot, the Workmen call the Metal, which when it comes to harden in the cold, produces the finest Glass. If this now was not evident from common Experience, what mortal living cou'd ever have imagined, that a solvent Alkali, spontaneously dissolving in the Air, cou'd, when it was rendered vastly active by the intenseness of the Fire, be converted with the Solvend into a metalline Mass perhaps, setting aside its want of malleability? This property, therefore, of Alkali's, must by all means be inserted in this account of the power of alkaline *Menstruums*. For here, when the Alkali, by the action of Fire is made to flow like Water, it hence becomes capable of dissolving the Powder of the Flints in the same manner, and by this very means becomes immediately so altered itself, that it retains nothing of its former disposition, but intirely acquires a new one. Hence, then, you see how *Menstruums*, and those very powerful ones too, may be joined in an indissoluble union with those Bodies which they have most intimately dissolved; which concretion is always so much the solider, as the Solution is more perfect. We learn, therefore, from this Experiment, that Alkali's, whilst they perfectly dissolve other Bodies, are hence sometimes so altered themselves, that they absolutely lose the nature of a Salt; for if there is any substance in Nature, that is intirely different from Salt, Glass, certainly, must by every-body be judged to be such a one; notwithstanding it is near a third part Alkali. And in this Operation, is it not very remarkable, that this alkaline Salt, shou'd, in the very act of Solution, so immediately put off its alkaline Nature, as soon as ever it is converted into Glass? For of all the proper characteristics of an Alkali, there is not so much as one left. It has lost all its Taste: It does not cause an Effervescence with any Acid: It makes no alterations in Colours: It becomes exceeding soft, and perfectly free from any caustic Acrimony: Nay, it is much more fix'd in the Fire when it is turned into Glass, than it was before, when it existed in form of an alkaline Salt. But how very difficult is it now to be put into fusion, as it requires so strong a Fire applied to it for so long a time to make it melt? And which is still more surprizing, as soon as ever it begins to flow, and is converted into Glass, it becomes a tenacious Mass cohering together like
Pitch,

Pitch, and is so ductile, and pliable, that you may form it into whatever shapes you please: Nay, and if you thrust an Iron into it, it will so adhere to it, as to come out of the Melting-pot with it, and be retained upon it. But we still farther observe here with admiration, that from two Bodies exceedingly opake, concreted into one solid substance, should be formed one so pellucid, that in the best sort of it we find the transparency of pure Water. And lastly, to detain you no longer, we see here a Body produced by solution, and that from a fixed alkaline Salt, which of all Salts is the most soluble, which itself cannot be dissolved by any known *Menstruum* whatsoever. Upon this, neither Water, Spirits, Oils, acid, alcalious, simple, or compound Salts, nay, nor the very *Spiritus Vini Philosophicus*, the *Sales Circulati Philosophorum*, nor even the *Mercurius Philosophorum* has any influence: For the Adepts *bona fide* assure us, that all these *Menstruums* are produced within glass Vessels: Nay, and they unanimously agree, likewise, that all their digestions, distillations, circulations, fixations and solutions of all Bodies whatsoever, they perform with their *Menstruums* in Glass alone. And, which is still more, even the secret Operations of the Alcahest itself, by which they tell us, all Bodies are converted into Water, are brought to perfection in glass Vessels, without their suffering from it any manner of alteration. Do not we, then, hence evidently learn, how difficult it is for a Philosopher to explain the origin of a given natural Body? How vastly hard to assign the Principles of which it was at first compounded, by plainly resolving it into those Principles, in such a manner, as by compounding them again certainly to produce the same kind of Body? If a man was perfectly acquainted with every other part of Natural Philosophy, but know nothing at all of the Art of Glass, what judgment, with all his skill and application, could he make of a piece of Glass that should be given him to examine? Certainly, as far as I am able to judge, he would not find the least indication by which he could possibly suspect that this Substance was concreted in an intense Fire, from an alcalious Salt, and calcin'd Flints? What a task then do the Philosophers undertake, when poorly furnished with Experiments, they dispute about the origin, nature, and principles of natural Chrystals, and even Gems themselves? We had better, certainly, in these cases, confess we are in the dark, than to hope such mighty things from our narrow capacities. For the difficulty of coming rightly at the knowledge of these things does not depend only upon the nature of the concurrent Principles, but also upon that surprising effect of Fire, by which those very Principles are altered at the time they are coalescing into one Mass.

Having thus, then, examined into the origin and nature of alcalious *Menstruums*, and explained their effects upon various, and, indeed, the principal kinds of Bodies, we must observe, before we proceed, that from what has been said it appears, that more or less of the acid Salt contained in the Vegetables, by burning which the Alkali was produced, may still adhere to it; and, consequently, that this alkaline Salt will be of a different nature from what it would have been, had it been perfectly free from this Acid. And the same must likewise be conceived of the adhering Oil and Earth. Hence, therefore, according to the various proportion of these Principles, the common Alkali's will be very different. Nor for this reason is it at all a wonder, that

Difference of
Alkali's
with regard
to their
purity.

some writers should give us an account of Experiments performed by Alkali's, which, upon being afterwards tried by others, would not succeed; for it is not unlikely, but that the alkaline Salt they made use of was of a different nature.

From other
Bodies added
to them.

But there is likewise a very surprizing caustic, and consuming quality communicated to Alkali's, by mixing them according to art with Quick-Lime, made of burnt Oyſter-shells, or stony Sea-plants, but, particularly, of alcalious calcin'd Flints. For by this means such a fiery, acrid, Alkali is produced, as being boiled with them, will soften and dissolve almost all the Solids, both of Animals and Vegetables; so that here you have the most acrid, alkaline Solvent procured from the same matter, which, we observed before, produced mild, unactive Glass, viz. this *Calx* and an Alkali. Nay, and this Alkali, when it is thus rendered more acrid with Quick-Lime, and is dried with a pretty strong Fire, will easily melt almost the Wax; and hence, if any Bodies are thrown into it, it acts upon, and dissolves them in a very particular manner. Was this the secret which some of the ancient Alchemists made use of, when they tell us they performed some very singular Operations, by means of an Alkali that melted with a gentle Fire? Might not this possibly be their *Sal Tartari inceratus*, so called, because, like Wax, it dissolv'd so easily in the Fire?

Limits of an
Alkali.

We have now, I think, treated sufficiently of Alkali's. In the mean time, however, it is necessary I should just observe to you, that Alkali's act with no dissolving power upon pure Mercury; for compound these two Bodies together in whatsoever manner you please, the Mercury is not found to suffer any alteration. And hence, therefore, upon those Metals, which the Adepts tell us are made up of the purest Mercury, and an igneous, metallic, sulphureous, fixed Spirit, with regard to the mercurial part, they are able to effect nothing by way of solution. Gold, therefore, and Silver, to the best of my knowledge at least, suffer no alterations from Alkali's. Upon the other Metals, indeed, an Alkali is found to act with more efficacy; perhaps, because these have some other Matter united with their mercurial part, which coming near to the nature of an Oil, or a Sulphur, is more exposed to the action of an alkaline Salt. And as these external Sulphurs do not suffer themselves very easily to be separated from the metalline Glebe, with which they are concreted, hence it often happens, that whilst alkaline Salts are acting upon the Sulphur, they seem to induce a change, likewise, upon the mercurial part which is closely united with it, though, in reality, they don't at all affect the nature of the Mercury. This I learnt evidently in melting common Antimony with Salt of Tartar; for the whole Substance, as well the mercurial part of the Antimony, as the sulphureous, was dissolved into one brown Mass, without any *Regulus* subsiding. But if you take *Regulus* of Antimony, from which the external Sulphur is first separated, and melt it with a fixed Alkali, then the Alkali, when it is in fusion, swimming at top, will extract still something of Sulphur, and by this means tinge the alkaline Salt with a golden colour; and at the same time, the reguline, mercurial part of the Antimony which lies under it, will become purer, and of a finer Silver colour. Hence then the power of Alkali's, considered as *Menstruums*, upon Metals, seems to be limited; for though you apply them even to calcin'd Metals,

Metals, they don't appear to be able, by the action of Fire, to penetrate into that Sulphur which fixes their Mercury into the form of particular Metals. Certainly, after all the contrivances that have been made use of, the production of a metallic Mercury, by the assistance of fixed Alkali's has not succeeded. Nay, the very greatest Masters of the Art, after so many Experiments made for this purpose, have declared, that they believe these Mercuries have been seen rather in idea, than in fact. For my own part, after taking a great deal of pains in this matter, I confess, the event has not answered, as has been promised. If, therefore, those things are true, which Boyle, Tacchenius, Homberg, and others have wrote concerning the resuscitation of the Mercuries of Metals, there must be some secret method of making the resuscitating Alkali's penetrate even into their fixing Sulphur.

Passing these things by, therefore, the first and principal vertue of Alkali's Its Action. seems to be this; that if they can but be applied, and determined in their action upon animal, vegetable, or fossil concretions, whether fixed or volatile, so far as they are of an oily, balsamic, gummy, resinous, or gummy-resinous nature, and therefore howsoever concreted from oily substances, they intimately open, attenuate, and resolve them all, and dispose them to be perfectly miscible with Water, Alcohol, and Oils; the same effect, likewise, they have upon pure, proper Sulphurs, or these compounded and mixed with other substances. Hence Alkali's come to be the principal instrument in extracting what the Chemists call Tinctures. By the help of these are prepared, according to the opinion of these Gentlemen, at least, the most noble Medicines. Gum-Ivy, Juniper, Lac, Myrrh, and others, are not dissolved by Water, or Alcohol, without a great deal of difficulty; but if they are first properly prepared by these Alkali's diluted and heated, they dissolve in them very easily, and if they are then dried with a gentle Fire, they will excellently give out their vertues in solution. In the second place, when the elements of any Bodies are concreted together by means of a *Gluten*, or an Acid, interposed between them, then these Alkali's often bring about the Solution desired, by attracting into them the coagulating Acid, and by this means removing the *Vinculum*, and setting the Elements again at liberty. We are sensible, indeed, that these Acids are often so intimately united with some Bodies, that they won't be very readily, nor so perfectly fetched out the first time by these Alkali's; but still at last they generally yield to them: Mercury, when it is once accurately corroded by Spirit of Nitre, and then by the action of Fire converted into *Mercurius præcipitatus Ruber* does not, upon pouring on of Oil of Tartar *per Deliquium*, immediately return to fluid Mercury, but is changed into another Powder; but yet if this is put into a retort, and forced off from this alkaline Salt, with a strong Fire, the Mercury will leave its Acid united with the Alkali, and will recover again its pristine form. In the third place, if to some Bodies, when they are dissolved into their smallest Particles by an acid *Menstruum*, you apply pure Alkali's, these Alkali's often acquire a new vertue, by which being more intimately admitted to these Elements, they dissolve them much more efficaciously than if they had acted upon the same Bodies without this previous corrosion by the Acid. And hence we see, that in most of the methods by which the Alchemists have endeavour-

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A volatile
Alkali.

ed to procure fluid Mercury from Metals, they first order you to calcine them with Acids, and then mix and agitate them with Alkali's.

In the last place, now, it is necessary we should say something of volatile, alcalious *Menstruums*. Whether any volatile Alkali, then, ever naturally existed, as such, before the putrefaction or distillation of Animals or Vegetables, I won't pretend absolutely to determine. Some persons, perhaps, may be of opinion, that that singular Salt, which is found in chalybeate Waters, should be referred hither; but this I think must not be done without proper deliberation, as this cannot by any Art whatever be made to resemble the other volatile Alkali's, in all its characters; though it may be more properly, indeed, referr'd to these, than to Acids, as the famous *Hoffman* has elegantly proved in his writings upon this subject. The Bodies, however, of all Animals whatsoever, and those of Vegetables, that will putrify, are constantly so altered and disposed by putrefaction, as to have their saline Principle become a perfect volatile Alkali. The acrid Vegetables that we formerly mentioned will yield these Salts, by simple distillation; as do all Animals, likewise, that have been hitherto examined. And lastly, if the juices of Animals, not yet alcalious, are mixed with a fixed Alkali, they are so changed, that the other part being attracted into the fixed Alkali, they instantly send forth an alkaline Vapour, and by the action of the Fire yield immediately a volatile Alkali. This Salt, now, though produced after so many different manners, if it is perfectly purified according to art, will have exactly the very same appearance, and the same virtues: And these virtues are pretty nearly the same as those of fixed Alkali's, though in some measure, however, they differ from them in their effect, as plainly appears upon comparing them together. Volatile Alkali's, spontaneously, or in a very small degree of Heat, are always themselves in motion and action: Fixed Alkali's require a much greater assistance from the Fire, to make them efficacious. Volatile Alkali's soon fly off by Heat, and consequently from the Substance to be dissolved, if heated, and therefore do not continue applied to it in such a manner as to be able to exert its power upon it; whereas fixed ones, on the other hand, by means of the Fire that keeps them in agitation, persists to act constantly upon the Body exposed to them, if that is itself of a fixed nature, and does not quit them. When volatile Alkali's, however, are made to adhere to the solvend Body, they then, in a moderate Heat, become vastly efficacious, and that too very quickly. This appears evidently in the pure Alkali of Urine, which, if you apply it to the human Body, and cover it over with an adhesive Plaister, there instantly arises in the part, Heat, Pain, and an Inflammation, succeeded by a black, gangrenous Eschar, and an Erosion to the very Bones. These differences, then, being thus taken notice of, the other properties of volatile Alkali's may be learned from the History of the fixed ones. Let us, therefore, briefly take a view of,

Acid Menstruums.

Native, vegetable Acids.

The physical character of an Acid has been given already; and upon examination it has appeared, that Acids rarely exist in a solid form, except in the essential Salt of acid and austere Plants, and in Tartar. But whatever Acids have been found in Vegetables, and Fossils, I have never yet known

any

any proper to Animals. Vegetable Acids are either native, or produced by the help of Fermentation. Native vegetable Acids, seem to owe their origin intirely to the Juices that the Plants draw out of their mother Earth; and hence, perhaps, all these may, in this respect, be look'd upon as of the nature of Fossils, especially as the Plants, that grow in the Sea, and have not their Roots inserted into the Earth at its bottom, consist purely of alcalescent parts, and in distillation yield an oily, volatile Alkali, as the illustrious Count *Marfilli*, in his Writings upon this head, informs us, he long ago observed. In some Vegetables the native Acids discover themselves evidently; as in Sorrel, the *Trifolium Acetosum*, and the Juice of all Fruits, whether the Pulpous, or Summer Fruits, especially before they are ripe, for afterwards, being concocted by the warmth of the Sun, they in some measure lose their acidity, and grow more mild. In the spring time, too, when Vegetables begin to put forth, and show again new signs of Life, the Juices often contain a perfect Acid, nearly like that of Vinegar. In other Vegetables there is likewise a true Acid, but it lies more concealed, as in Woods, and Aromatics. In Guaiacum, Sassafras, Cinnamon, and a vast many more, who would ever have expected an Acid, if it had not appeared so evidently by distillation? In the noblest Balsams, who would have thought of any such Acid as Turpentine, when it is distilled, yields so easily, and in such great abundance? These Acids, indeed, can scarcely be obtained pure, but are blended with other Bodies, and hence it is exceeding difficult to treat clearly of their proper action: The vertue of some of them, however, upon certain Bodies, is evident, as we see the fresh Juice of Oranges, Citrons, and Lemons, dissolves Lead, Tin, Copper, and Iron, and pretty strongly calcines them, as well as fossil Acids. These acid Salts, however, are formed into solid Globules, in a different manner from the other. *viz.* by taking the very thin, expressed, acid Juices, filtering them, inspissating them, and then letting them stand quiet, till they shoot into saline Chrystals; of these I have shewn you some every year procured from Sorrel, which are exceeding like Tartar, and have the true native vegetable acidity.

But fermentation seems more and more to exalt the latent Acid of Vegetables. For the Juices of Vegetables that are exceeding ripe, and sweet, appear to have hardly any thing of acidity in them, as we see evidently in the expressed Juice of Grapes, Cassia, Manna, Honey, and Sugar; and yet when these are rightly fermented, and set a working, an Acid may be presently drawn from them, but especially when the Wine begins to grow finer and more subtil. In ripe, mealy Corn, is there the least indication of an Acid? And yet when this has fermented but a very little while, it discovers an acidity. As these Acids, now, thus produced, are of a something different, and more subtil nature than the native ones; hence, to distinguish them, we may be allowed, for the future, to call them vinous Acids. These vinous Acids then are of two sorts; for either they are dispersed through the Wine, in form of liquid Acids; or else in time collect themselves together in the Wine, and fix themselves to the surface of the Vessel, in the solid form of Tartar. And these fermented vinous Acids have pretty nearly the same vertues as the preceding native ones.

Acids, liquid
and solid,
call'd vinous.

But

Acetose
Acids.

But the Acids of Vegetables, now, produced by a second fermentation, with your leave, I will call by the name of acetose ones. For if any known Wines are with acid, rough, crude ones, made to undergo again a proper acetose fermentation, they will be converted into (*Aceta*) Vinegars, will consume their proper Tartar, become much more acid, and will acquire a stronger and more durable Acid, which will remain even in distillation: Hence in Vinegars there is obtained a pure, active Acid, and then they are called pure, distilled, acetose Acids. These last, now, are of such incredible service and efficacy in the chemical art, that hence all other *Menstruums*, likewise, have been called *Aceta* too, as appears evident in the *Aceta Philosophorum*.

Fermenting
Acids.

But among these Acids, we must take notice, likewise, of fermenting Acids; by which we mean, vegetable Juices, that are in the very act of fermentation, and thus in a kind of middle state between their natural one, and that which they pass into when the fermentation is perfectly compleated; for during this time, the most elastic part of the fermenting Liquid acquires such a power as is not to be equalled by any thing I know of in all nature. For if this (*Sylvestris*) Sylvestrian, incoercible, explosive, acid Spirit, rising from a vast quantity of fermenting Vegetables, should pass through a very small vent-hole into the nostrils of the strongest man, it would strike him dead in an instant. If it does not act with all its force, it causes a sudden Apoplexy; if less powerfully still, a Childishness, with a *Paraplegia*; if very lightly, only a Giddiness. The truth of all this has been too certainly evinced by melancholy instances. Hence we come to have a more perfect idea of the more immediate cause of drunkenness, and the tremors upon the Nerves, that are a consequence of it. And hence we see the occasion of that surprizing *Phenomenon* mentioned by the illustrious *Cornaro*, in his noble treatise wrote in the praise of Sobriety, where he tell us, as he grew in years, he was annually, just before the time of vintage, troubled with a *Languor*, and lowness of spirits, which would not give way to any Medicine, or Regimen, but increased so as to become extreme, till, upon drinking new Must, he recruited his exhausted Spirits, and returned again to his former Vigour: This, then, he continued to enjoy till the Wine of that year began to grow old, and then relapsed into his usual debility, and was forced to wait for a fresh recruit of new Wine to set him to rights again. From all this then we evidently learn, what an incredible effect this fermenting Acid has upon the Bodies of Animals, either for their detriment, or their advantage. Whence does it happen, that the *Cholera Morbus*, in so short a time becomes so fatal? Certainly from Must, and ripe Summer Fruits, actually fermenting in the Stomach, and smaller Guts, and by the explosion of their Spirits, contracting the Muscles of these parts into spasms, that often prove mortal. Of this there is a remarkable instance in the *British Philosophical Transactions*, where that excellent Anatomist, St. Andrew, gives a very accurate account of the Body of a Man that fell into a *Cholera*, upon drinking a large quantity of bottled Ale, of which he died, in the manner there described. As by these accounts, now, the singular efficacy of such an Acid does evidently appear, so likewise it seems exceeding probable, that those Spirits, considered as a *Menstruum*, produce often upon other Bodies very surprizing effects. And I have sometimes doubted, whether this wonderful Spirit is not fixed in Tartar, and afterwards, when by the action of the Fire, in the distillation

distillation of this Salt, it is set at liberty, does not produce that elastic Vapour which the Chemists have always observed to be so vastly powerful, as to be able to burst to pieces all their Glasses, let them be ever so large. In the mean time, however, this is certain, that if Bodies that we want to be dissolved, are put into fermentable substances, in the very act of fermentation, they will be dissolved by them in a very different manner from what they would have been, had they been mixed with them, when they were not assisted by this fermentative power. This is evident in throwing green Herbs into Wine, or Ale, when they are working; for hence you have a Liquor in which all their virtues seem to be most equably united into one and the same Liquid, and afterwards to act with a joint efficacy. And thus the different ingredients in *Theriaca*, when they are mixed together with Honey, are reduced into one homogeneous Mass, and conspire together in the same operation.

But pure, thin, acetose Acids, are procured pretty much in their natural form, from Vegetables exposed to the Fire: For if you take a stick of Wood, a green one in particular, and lay it upon a clear Fire, in such a manner, that both the ends shall lie out, then the Fire acting upon the middle part of the Wood will fuse the humours that are contained there, and in form of Water drive them out of the extremities with a hissing and froth: And this Liquor, when it is examin'd, appears to be a pure Acid, has all the properties of Acids, and the dissolving qualities common to them. Hence, then, we learn, how the Smoke of Wood, that which is green in particular, makes the Eyes smart so violently, viz. by the acrid Acid which it disperses all about. This, likewise, when it penetrates into Flesh or Fish, that are hung in Smoke, tinges them with a red colour, and by its acidity prevents their growing putrid, or rancid. And this Acid is exceedingly like those that exist naturally in most Trees.

Acid vegetable by burning.

But again, there are discovered other very singular Acids, that are in some measure of a balsamic, and oily nature, which are drawn from Vegetables by Fire in a close Vessel, both *per adscensum* and *descensum*. Thus the Wood of Guaiacum, Juniper, Oak, and a vast many others, if you reduce them to dry Shavings, and carefully distill them in a Retort, yield a limpid, reddish Liquor, which is very acid, somewhat oily, and has a good deal the smell of a Herring dried in Smoke. And the Liquid thus prepared is strongly acid, especially if it is depurated by Filtration, and letting it stand quiet, called rectification; and the acid solvent virtue of this *Menstruum* is perfectly singular. In the human Body it produces wonderful effects, by attenuating, preserving, stimulating, and resisting putrefaction, and carrying off the noxious Matter by Sweat and Urine. If in these *Menstruums*, therefore, the medicated virtues of Plants are dissolved, the solutions become exceedingly efficacious; as they act by their very subtil, penetrating, singular Acid, and exalt the qualities of the Bodies dissolved in them. Of all these vegetable Acids, therefore, it is true, that they are capable of intimately dissolving many animal, vegetable, fossil and metalline Substances: By digestion and coction they dissolve the Horns, Hoofs, Bones, and Flesh of Animals: The Shells of Fish, and other Animals, they perfectly corrode into a pellucid Liquor: And Metals they dissolve, as I hinted before, except Mercury, Silver, and Gold.

The same distilled.

O o o

Art,

Art, therefore, has fought out and discovered other Acids, which are able to dissolve Mercury, Gold, Silver, and other Fossils, which were unaffected by vegetable Acids, and hence were not easily managed by the power of human Bodies. For vegetable Acids may, by the action of a strong healthy Body, especially if assisted by a considerable motion, be so changed, as to lose their Acid nature, and be converted into another kind of Salt: But those Acids that we are at present acquainted with, which are capable of dissolving Mercury, Gold, and Silver, are not so easily subdued by the concoctive, animal powers, but being superiour to them, for the most part destroy them. And hence these become almost Poison to Animals, except in a very few cases, where a putrid Alcalescence prevails, as when alcalious Poisons are taken in by them, or in a putrid state of the Humours, as where the virulence of a Plague, or the sudden putrefaction of the Small Pox are to be dealt with.

Native, very
rare.

Fossil, native Acids, now, are found to be very few, since it has been discovered, that the medicinal Waters once looked upon as acid, approach, in every character, nearer to an Alkali. There is often, indeed, a Vapour observed in Mines, which resembles a suffocating, sulphureous Acid, and by other marks demonstrates its acidity: But it is exceeding seldom that it is found alone, and very pure, in form of a Fluid.

Fixed ones,
frequent.

But whenever it happens, which is very often the case, that it meets with a solid Body, that is capable of attracting that Acid, it then unites with it, and becomes fixed, and capable of examination: And when it is afterwards drawn out of that fixed Body, it then falls under the notice of our senses, and then, as far as one is able to judge of it, appears to be always one and the same.

In Sulphur.

For, as I formerly took notice to you, if it lays hold of a pinguious Fossil, it produces the various kinds of Sulphurs, which if they are burnt, emit Fumes, which being collected, refrigerated, and mixed with the humid Air, yield the Spirit, or Oil of Sulphur *per Campanam*. If you take this, now, and put it into a clean glass Vessel, and expose it a good while to the heat of boiling Water, you will distill from it a considerable quantity of pure Water, which, whilst the Sulphur was burning, had insinuated itself out of Air into the Acid; and there will then remain at the bottom a ponderous, thick, caustic Acid, which in every character resembles the purest Oil of Vitriol, except in this alone, that it contains nothing of a volatile Metal, which is always more or less in Oil of Vitriol.

In Alum.

But if this acid happens to get among Lime-stones, and corrodes them, it then produces Alums, which are of different kinds, according to the diversity of the matter that is mixed with them. All these, now, if they are first lightly calcined, and then with an intense Fire urged into Vapours, will by the condensation of these yield a Liquor, which, when it is purified according to art, is the very same with the former procured from burning Sulphur, without any difference at all.

In Vitriol
of Iron.

Again, if you take native green Vitriol, and by the help of a moderate Heat reduce it to a dry, white Powder, and then by gentle degrees expose it to the Fire, till you come to the greatest, it will emit white, cloudy Vapours, which collected into a Liquor, and accurately depurated, is the very same again as was obtained from the Sulphur, and Alum.

The

The blue vitriol, likewise, if it is treated in the same manner, gives a liquid, ^{In Calcan-} which is the same with the former, nor can be distinguished from them, when ^{tbum.} it is rectified according to Art. All these acid Liquors, now, if they are urged with a heat of 560 degrees, boil, emit white cloudy Fumes, which disperse themselves about, and float to great distances, and destroy all Animals we are acquainted with, even Insects themselves. If they happen to be drawn into the human Lungs, in their full force, they presently excite an acute Cough, not to be removed, and then a suffocating, fatal *Dyspnæa*, with sudden death: Or if from some concurring circumstances they don't act so violently, they bring on a most troublesome Asthma, that continues during life. And the very same effect has Oil of Sulphur, Alum, Vitriol of Copper, and Copperas, as soon as ever, by the action of the Fire, they are raised into Vapours, by combustion, distillation, or ebullition. Nay, and take any of these Acids, which you please, unite it with a pinguious Oil, and it produces a Sulphur; with Lime-Earth, an Alum; with Iron, Vitriol of Iron; and with Copper, Calcanthum: From all these considerations, then, we are induced to believe, that the native acid, so ponderous, and difficult to boil, which is found in the fossil Kingdom, is always one and the same, that is to say, if you consider it as existing in form of a pure Acid. The properties of this Acid, now, are, first, that it is naturally the heaviest of all Acids. To Spirit of Nitre its specific gravity is as 11 to 9: To Spirit of Salt, as 11 to 8: To *Aqua Fortis*, as 11 to 9: And to distilled Vinegar, as 11 to 7, nearly, *Mem. de l'Ac. Roy. des. Sc.* 1699. p. 47. Secondly, it is of all Acids the most fixed; for in the heat of boiling Water it never emits any Fumes, except by means of the Water that adheres to it, not of the Acid itself: If you urge these Acids, however, with something more than 560 degrees of heat, they will then boil; and at the same time will send forth noxious Vapours. In the third place, these Acids, being perfectly freed from all their Water, by a strong Fire, and hence being rendered very pure, heavy, and acrid, very greedily attract into them Water out of the Air, and by this means dilute themselves, and increase their weight. Fourthly, the same thus rendered very pure, grow very hot immediately, upon the effusion of cold Water. In the fifth place, this Acid induces such an alteration on Sea Salt, Fountain Salt, and *Sal Gem*, by the assistance of Fire, that in distillation they yield a Spirit of Salt; mixed with Nitre, it causes a Spirit of Nitre to rise from it; and if it is mixed with many other Bodies, dissolved by acid Spirits, it sets them free from their solvent Acids, by dislodging them, and rendering them volatile, whilst it often takes possession of their place itself. Upon this principle it is that Alum, and Vitriol, if they are first calcined, and then mixed with Nitre, yield *Aqua Fortis*; if with Sea Salt, Spirit of Sea Salt: For in the Colcothar there still remains a latent Acid of Vitriol, exceeding strong, and so fixed, that the Fire was not able to expell it, which being mixed with the Nitre, makes the acid Spirit of the Nitre rise into *Aqua Fortis*, which is the pure Spirit of Nitre, without any mixture of Oil of Vitriol; but at the same time, that part of the vitriolic Acid which remained in the *Calx* of the Colcothar, is left at the bottom with part of the Nitre, and produces there an exceeding fixed Salt, like *Nitrum Vitriolatum*. And the case is the same in the Sea Salt. In the sixth place, it readily dissolves Iron, Copper, somewhat slower, Silver with a good deal of difficulty, and Mercury not in less

than 560 degrees of Heat: Lead and Tin it don't dissolve at all. In other respects, this Acid agrees with the rest. It has this too in common with some, that it will perfectly dissolve Camphire into a liquid Oil, which by the effusion of a good deal of Water, may be recovered again into true Camphire.

Acid of Nitre.

But there is another sort of fossil Acid, likewise, that is procured from Nitre, nor ever was discovered any where, even in the smallest quantity, 'till it had been first drawn from that Salt. For if you take Nitre, and intimately mix with it three times as much Bole, Clay, Brick-dust, or any thing of the like nature, and urge it with a very strong Fire, a great part of it will be converted into red Fumes, which being collected into a Liquid, are called Spirit of Nitre. Or if you distill dry Nitre, with an equal quantity of Oil of Vitriol in the strongest Sand-heat, but gradually increased, you will then likewise from red Fumes have the same Spirit of Nitre. Or lastly, if you rub Nitre with an equal quantity of the *Calx* of red Vitriol, or Alum, and then urge it with a very great degree of Heat, it will then again emit the same Fumes, and from them yield a spirit of Nitre, which is as good, and as pure, as the former, but is then called by the Artists *Aqua Fortis*, *Aqua Stygia*, and *Aqua Docimastica*. This Spirit, now, howsoever prepared, is the same in every mark, and every property; for if there is any difference, it scarcely discovers itself by any Experiment. And it has this peculiar in it, that when it grows very hot in the Fire, it always sends forth very red Fumes, and dissolves Silver into very bitter caustic Chrystals; which Solution is proper to this Spirit, and can scarcely be effected by any other Acid, even pure Oil of Vitriol not doing it without difficulty. It dissolves Mercury, likewise, Lead, and Copper. Gold it does not affect; and scarcely dissolves Tin. This Acid, when it has dissolved its Metals, and intimately mixed itself with them, adheres to them with a considerable force, so as to remain united with them, in a pretty strong Fire. This appears evidently in Silver dissolved in this manner, which suffers itself to be melted into the *Lapis Infernalis*, without letting go its corroding Acid. *Mercurius præcipitatus Ruber*, too, when it is rightly fixed, how long will it resist an intense Fire, before it parts with the Acid that adheres to it?

Acid of Sea-Salt.

Sea-Salt, as Nitre, when it is pure, discovers no sign of an Acid, but if it is treated in the same manner we just now mentioned of Nitre, it is changed into a volatile acid Liquor. For if to prevent its melting, you mix it with three times its weight of Earth, and then urge it gradually till you come to the greatest degree of Fire, it will be dissipated into dense, white Fumes, that float about, are very volatile, and being collected form a Liquid of a golden or green Colour. If you distill it with Oil of Vitriol, you have the same Liquor, but more volatile. And if you mix it with the *Fæces* of distilled Alum, or Vitriol, and afterwards expose it to a very strong Fire, it will then likewise give out the same Spirit of Sea-Salt. And these Spirits, prepared in these three different ways, are intirely one and the same. Nay, and they will be the same, if you make them with *Sal-Gem*, Fountain, or Sea-Salt. This Spirit, now, has this peculiar in it, that if it is drawn from the purest Salt, and you repeat the distillation upon fresh pure Salt, when it begins through the violence of the Fire to grow exceeding hot, it emits white Fumes, and dissolves Gold, which

which no other Acid in nature is able to penetrate. It likewise dissolves Tin, Mercury with a flatulent noise, Iron, and Copper. Silver it does in no manner affect; nor perfectly dissolves Lead: So that this again is an Acid perfectly singular in its kind.

Hence, therefore, it appears, that Spirit of Nitre, and Spirit of Salt, are two perfectly distinct things, tho' at the same time they surprizingly approach to one another, and are converted into one another with wonderful ease. This certainly, then, in the History of *Menstruums*, ought well to be considered, and is as follows. If Spirit of Nitre is cohobated in a glass Retort upon Nitre that is exceeding dry, and purified with the utmost skill, so that there is not the least grain of Sea-Salt in it, you will then have the very choicest Spirit of Nitre, growing better and better upon every cohobation, and fitter for the Operations proper to this Spirit. But if this cohobation is performed upon common Nitre, which is not purified by chrySTALLIZATION, then the cohobated Spirit of Nitre will lose the nature of Spirit of Nitre, and will acquire the disposition of Spirit of Sea-Salt, or *Aqua Regia*, and will dissolve Gold. If we carefully examine, now, this extraordinary *Phænomenon* we shall easily perceive, that to this natural Nitre there must adhere somewhat of Sea-Salt, which intermixes itself with the nitrous Spirit in distillation, and thus from Spirit of Nitre produces *Aqua Regia*. And this again appears evident from the following Experiment. Take one part of pure decrepitated dry Salt, reduced to Powder, put it into a clean Retort, and pour upon it four parts of good Spirit of Nitre, or *Aqua Fortis*. Distill it then according to Art, to the utmost dryness, keeping your Sand-heat very strong to the last; and the acid Spirit which is thus procured, will be no longer *Aqua Fortis*, but *Aqua Regia*, which will dissolve Gold, but will not touch Silver. If you examine, then, the Salt, that remains at the bottom of the Retort after this Operation, by Solution, Filtration, and ChrySTALLIZATION, you will have a true, pure, inflammable Nitre. *Du Hamel. Hist. de l'Ac. Roy. des Sc. p. 158. Boyl. Or. Forms. p. 215.* Again, if you take one part of the purest Nitre, and two of the best Spirit of Sea-Salt, and distill them in a proper manner in a Retort, there will come off a Spirit which will dissolve Gold much easier and sooner, than Spirit of Sea-Salt. And the Salt now again that remains at the bottom after the strongest distillation, if you dissolve it in Water, filter, and chrySTALLIZE it, appears to be a good inflammable Nitre. *Boyle. Ib. from p. 215. to 224. Bobn. Chem. 35, 36, 163. Hoffm. Disert. Chem. Phys. L. iii. Obs. 20.* Hence, therefore, it appears that *Aqua Fortis* becomes *Aqua Regia*, as soon as ever Spirit of Nitre and Spirit of Salt come to be mix'd together, in whatever manner, and almost in what proportion soever: Nay, and if to *Aqua Fortis* you add *Sal-Ammoniac*, *Sal-Gem*, Sea-Salt, Fountain-Salt, the *Sal Febrifugus Sylvianus*, or true Spirit of Salt, in all these ways there is constantly produced *Aqua Regia*.

Thus then we have given you the History of Acids as it stands at present. And in this, it is particularly remarkable in the first place, that Acids are so easily generated from Non-acids; as appeared above in the Acids of Vegetables. Wine too, not at all acid, has, by being close stopped up in a clean Bottle, and tied to the Sail of a Wind-mill, been converted in three days into good Vinegar, according to the Observation of Monsieur *Homborg. Mem. de l'Ac. Roy. des Sc. T. II. p. 11.* But in the second place, it deserves well to be taken notice of, likewise,

Acid *Aqua Regia*.

Corollarics.

likewise, that Acids, when they are once produced, will bear the Fire for a long time and be scarcely altered: For *Aqua Fortis*, *Aqua Regia*, Spirit of Nitre, Spirit of Salt, and Oil of Vitriol, being included in Glasses hermetically sealed, and exposed for four years to the equable Heat of an Athanor, retained the same dissolving power: Vinegar only was grown insipid, and had acquired an aromatic Smell; and the Spirit of Salt had begun to corrode the Glass. In the third place, however, these same Acids lose their acid nature, whilst they act as *Menstruums* upon solvend Bodies. This Monsieur *Homborg* very ingeniously inferred from a tedious Experiment performed with Mercury and Spirit of Nitre. *Du Hamel. Hist. de l'Ac. Roy. des Sc.* p. 442, 443. Hence, therefore, it appears, that the strongest acid *Menstruum*, is, by dissolving its object, converted into an insipid, unactive Fluid, not unlike Water, and deprived of the proper solvent Power which it had before: And hence, perhaps, it is not improbable, that these Acids are generated, and perish. For what Person living has ever discovered any Spirit of Nitre in the World, which was not first procured from pre-existing Nitre? And yet Nitre is produced from Earth, filled with animal Excrements Lime and an Alkali, and Air; or from pure Spirit of Nitre attracted into a pure Alkali, particularly a fixed one. Rich and fruitful Lands too, defended from the Rain, and perfectly prevented from consuming their strength by nourishing of Vegetables, are all found by length of time to be impregnated with a fruitful Nitre, if you take care that no Sea-Salt shall come at them. *Boyl. Scept. Chem.* p. 177. Hence, then, it is evident, that the acid Spirit of Nitre is, by the sole action of the Fire, produced from pure Nitre, altered; whereas native Nitre is produced without any such Spirit first existing. In the fourth place, therefore, these Acids, whilst they dissolve Bodies, become concreted with them, are changed, and converted into new ones, and thus from one, give rise to a great variety: For Spirit of Nitre dissolves Silver, Lead, wonderfully changes Tin, Copper, Mercury, Nitre, Antimony, Zincq, and Emmery, and with them forms new Bodies, that are different in Taste, Smell, Colour, Density, and all their effects. *Boyl. Mec. Qual.* 118, 119. In the fifth place, all these Acids agree in some particulars, but differ in others.

The agree-
ment of A-
cids.

They agree, with regard to the Effervescences they excite by being mixed with Alkali's, and the production of new Salts that arise from this combination. As likewise, in their composition with Chalk, Corals, Crabs-eyes, Pearls, Mother of Pearl, the Shells of Cockles, Limpins, and Oysters, Stones, Bones, Hoofs, quick and flaked Lime, Iron, and Copper: For all these are generally dissolved by all sorts of Acids sooner or later, whether it is effected quietly, or with a great *impetus*. These Bodies, now, when they are thus dissolved, always attract into them the acid of the Solvent out of the Water, in which that Acid was before diluted: And the dissolved Matter being by this means united with its solvent acid Salt, may afterwards be diluted in Water like a Salt, so long as its Acid adheres to it; tho' these Bodies before this Mixture were no ways dissoluble in Water. But when this Acid is again by any method removed from the dissolved Matter, then this constantly appears again in form of an Earth, which most strongly resists a Solution in Water. Hence, then, it appears, how very much we may be imposed upon by Water, whilst judging of it by its appearance, we make use of it in our Operations for pure elementary

mentary Water; whereas, in reality, it may contain in it various kinds of dissolved Bodies, together with their Solvents. And hence it comes to pass, that Effects are frequently supposed to be produced by simple Water, which in fact, are owing to these latent Solvents and *Menstruums*. And this, indeed, happens the more easily, because, Metals excepted, Acids in general, when they are accurately united with the Bodies abovementioned to a perfect Saturation, they lose all their Acrimony, and for the most part all their Taste, and thus lie perfectly concealed. * With of Spirit of Nitre, dissolve 4 drachms and 9 grains of Crabs-eyes, as it generally will, and let the Solution be carried accurately to the point of Saturation, and you will have a limpid, and almost insipid Liquor; let this then be diluted with very pure Water, and filtered, and let it stand for some time in a moderate Heat, and it will appear like clear Water; and yet, if you drop into it a strong fixed Alkali, the dissolved Body will all precipitate to the bottom, which a Person not apprized of the contrary, might suspect to be produced from the Water itself. These Acids farther agree in this, that by dissolving Bodies, they not only become united and concreted with their Solvents, but are likewise at the same time changed in their own nature: For it is demonstrated by undeniable Experiments, that the most acid Acids, whilst they corrode their Objects, are truly changed by them, and put off the disposition, not only of an Acid, but a Solvent likewise. Thus Spirit of Nitre, for instance, when it has corroded Mercury, and is separated from it again, presently loses the power of dissolving it any more. Another property of Acids in common, is their turning vegetable Juices of a red Colour, as appears in the Turnsole, Roses, and Violets. And again, they all agree in this, that they do not so much alter the Bodies they dissolve, as they are altered by them themselves. This is found to hold true in almost every case. Vinegar in dissolved Lead, does not continue Vinegar there, nor is separated Vinegar again; but the Lead is recovered perfect Lead. Spirit of Nitre dissolves Mercury, and the Mercury is procured from it again exactly the same; but the Spirit of Nitre, when it is separated, is nothing like what it was before. Hence, therefore, lastly, this likewise is common to all Acids, that many of them are continually destroyed.

But these Acids, now, on the other hand, differ very widely first of all, in the proportion between their true Acid, and the Water it is mix'd with. Thus in an ounce of the best Vinegar, there are 18 grains of pure Acid, and all the rest Water: In an ounce of Spirit of Salt, 73 grains of true Acid, the residue pure Water: An ounce of Spirit of Nitre, gives 2 drachms and 23 grains of Acid, the rest Water: The same quantity of *Aqua Fortis*, 2 drachms 26 grains: And, lastly, an ounce of Oil of Vitriol yields 4 drachms and 65 grains of Acid, according to the Observations of Monsieur *Homborg*. *Hist. de l'Ac. Roy. des Sc.* T. L. p. 52. In the second place, this same Acid, when it is pure in every particular sort, differs surprizingly in its dissolving power: For the Acid of Nitre boiled with Gold, has scarce any effect upon it, except changing it black; whereas it dissolves Silver presently: And the contrary is true of *Aqua Regia*. Hence then it appears, that the Acid does not act there as

Difference of
Acids.

* The quantity of Spirit of Nitre is not added, and our Author says it is not necessary; nor indeed is it absolutely so, as it will be determined by the Saturation: But then why he should mention such an odd quantity of Crabs-eyes, as 4 drachms 9 grains of Crabs-eyes, and add *ut solet facere*, I can't imagine.

an Acid in general, but as a Body endued with a peculiar vertue. In the third place, Acids differ likewise in this respect, that whilst they dissolve their Objects, some of them are changed a great deal more than others. Spirit of Vinegar, for instance, in dissolved Lead, becomes an oily pinguious Spirit: But Spirit of Nitre, whilst it corrodes Tin, is not altered in this manner. Fourthly, the same Acid is very much changed by acting upon some particular Bodies, but very little or nothing if it acts upon others. Thus distilled Vinegar, in the Solution of Lead, is altered in the manner I just now observed; if it corrodes Iron, it loses all its former nature, nor can be ever recovered from it again; but if Copper is corroded by it into a Mould, and then dissolved into a green Liquor, and from this you procure Chrystals, these Chrystals will contain an exceeding strong Vinegar, and if you distill them in a Retort with a great degree of Fire, you will have a very strong acid Spirit of Vinegar, scarcely at all altered, tho' it adhered so tenaciously to the Copper. Hence, therefore, it appears, what different changes are induced upon Acids by being united with different Metals; which is true in other Bodies likewise. All Acids in general, now, may be diluted in Water. They may be mixed with Spirits, as Spirit of Nitre with Alcohol, with a prodigious Heat, very red Fumes, and an Effervescence which almost bursts out into Flames. They may be combined likewise with Oils; Spirit of Nitre, sometimes, with such an agitation as excites Fire; for the most part with an intense Heat. Oil of Vitriol likewise, mixed with Alcohol, and Oils, makes the Compound vastly hot. But whenever Acids are intimately united with Oils, they almost always produce somewhat of a bituminous, pitchy, or sulphureous Substance; whence often arise very extraordinary changes. Thus, then, I think I have laid before you such an account of acid *Menstruums*, as is sufficient to enable you to judge of their action. We must now, therefore, briefly take under consideration those called the *Neutri*, *Hermaphroditi*, *Compositi*, and *Enixi*.

Of neutral Salts, as Menstruums.

Sal-Ammoniac a Menstruum.

And here let us first examine *Sal-Ammoniac*. This is very easily diluted in Water, nay and in a moist Air dissolves into a very acrid, and surprizingly penetrating Brine, which most happily attenuates, incides, opens, and resolves the thick, viscid, pituitous, and pitchy concretions formed in animal Bodies, and then expells them, by Perspiration, Sweat, Urine, and *Saliva*, and excellently too resists putrefaction. And for the same reason, if this Brine is boiled, or digested, with the Gums, Refins, or Gum-Refins of Vegetables, it intimately resolves them, and disposes them to be conveniently dissolved in aqueous, and fermented spirituous *Menstruums*. Upon Metals, likewise, it has beautiful effects. If you boil Filings of Iron in it, they are surprizingly dissolved, and converted into an excellent restorative aperient Medicine. If you boil or digest it with Filings of Copper, it gives a Liquor of a beautiful Colour, a few drops of which taken in a morning fasting, has often done great things in the Epilepsy, and Worms. On these accounts, this Brine affords a noble *Menstruum* in the Animal, Vegetable, and Fossil Kingdom. But when the exceeding pure dry flowers of this Salt are rubb'd for a long time, and accurately mixed with Fossils, and they are afterwards sublimed together in a Sand-heat, and in a close Vessel, they then, as a *Menstruum*, acquire inimitable

ble vertues. Hence the Chemists have called it the *Aquila Alba*, and the *Pistillum Sapientum*. Sulphurs, sulphureous Substances, Semi-metals, and Metals, treated in this manner, are vastly attenuated, opened, rendered volatile, and perfectly altered: And hence are prepared such excellent Medicines, as can scarcely be equalled by any other Art; witness the flowers of the *Lapis Hæmatitis*, the *Ens Veneris*, and *Ens Martis*, not to mention many more. What is more surprizing, than the various changeable Colours of Antimony thus produced from a black one? Let it suffice to take notice only, that many of the Philosophers have called this Salt, the Key, that is to admit us into the more profound parts of chemical knowledge. It has certainly this excellent quality, that it is scarcely altered at all by sublimation, except by means of some other Bodies joined with it. If it is mixed with *Aqua Fortis*, or Spirit of Nitre, it immediately converts these Liquors into *Aqua Regia*. If with fixed alcalious Salts, it is instantly changed into a very pure volatile Alkali, acting afterwards in that character, and into a new Salt pretty much resembling Sea-salt. From Spirit of Sea-salt perfectly saturated with a pure volatile alkaline Spirit, *Sal-Ammoniac* is produced; as it is likewise from Sea-salt, Urine, and Soot mixed together. Hence then it appears to be a true semi-volatile Sea-salt; and on his account its whole power, as a *Menstruum*, may be reduced chiefly to that of Sea-salt. Hence too it can never be made better than by subliming it some number of times in a Vessel accurately closed, from the purest, driest, decrepitated Sea-salt; for by this method are prepared the choicest flowers of *Sal-Ammoniac*.

Sea-salt comes next in order, which, as I have often taken notice of already, ^{Sea-Salt a Menstruum} is not only found in the Sea, but is dug likewise out of Pits, and procured too from Fountains: These three sorts, therefore, being perfectly the same, I shall describe them altogether under the name of Sea-salt. This Salt being, either by means of the Sea, Fountains, or Pits, distributed all the World over, proves a universal preservative against putrefaction. It readily dissolves in Water, and in a moistish Air spontaneously runs into a very strong Brine, which gives us the most beautiful, and defecated *Menstruum* of Sea-salt, the Effect of which, with regard to chemical purposes, is almost the same as has been ascribed to the Brine of *Sal-Ammoniac*, and which therefore may be applied to the same uses. This Sea-salt being set upon the Fire, will decrepitate, and then, in a dry, hot Vessel, may be readily reduced to a Powder, and melted in the Fire, at which time it will easily insinuate itself through the Pores of the Vessel it is fused in, and so disappear in the Fire. But when with this Salt thus in fusion, you mix Fossils, Metals, and Semi-metals, there are very strange alterations produced, peculiar, and different from all others. I took myself 8 ounces of moistish Sea-salt not decrepitated, and 2 ounces of common Antimony reduced to a Powder; and after they had been accurately mixed by rubbing them a long time together, I put them into a Crucible, which I covered with another inverted, and closed them together with a strong Lute. These being thus prepared, I put them in the Fire for four and twenty hours, and then urged them with such a Heat as to melt the Salt, after which the Crucible being opened, I found a blackish-brown Mass, at the top of which there stood up some white *Spicula*. I reduced the whole again to Powder, and luted the Crucible as before, and then obtained a reddish-brown Mass at the bottom

bottom of which there was somewhat of a more metalline nature. I repeated the same again a third time, and when it came to melt, almost all the Salt ran through the Crucible, and at the bottom I found a Mass of Antimony, which was of a reddish-yellow, and surprizingly changed. By this instance, then, it appears, how this Salt, as a dry *Menstruum*, acts with the assistance of Fire. There are an infinite number of other Operations, to which it may be applied with a very different effect, than what wou'd be produced by any other Salt. Hence in Cementations, this Salt mixed with Brick-dust in a dry form, is made use of to many beautiful purposes in the exaltation, separation, and maturation of Metals, concerning which *Paracelsus* wrote so largely in his Works, what other Persons since have found to be true. Among other things, we may take notice, that if dry Sea-salt is mixed with Brick-dust, and exposed to the Fire, it will be converted into a volatile acid Spirit resembling *Aqua Regia*, which will then act upon metalline Glebes like *Aqua Regia*, and hence perform very singular Operations. *Vid. Paracels. de Cæmentis, & Gradationibus.* But when by the method above-mentioned in the description of the acid spirit of Sea-salt, this Sea-salt is converted into a Spirit, and this Spirit again, by distillation, is drawn off from some of the same pure, decrepitated, dry Salt, and cohobated a good many times, you then obtain a singular and wonderful solvent of Sea-salt. These are tedious Labours, I confess, but they are usefull ones; and therefore, if you have a mind to repeat them after me, you may do it in the following manner. In two pounds of spirit of Sea-salt, by adding a little and little at a time, I dissolved as much fine dry powdered Sea-salt, as it wou'd possibly take up. This Liquor, by letting it stand quiet, and filtering it, I made exceeding pure, and then put it into a tall Bolthead, and fitting another smaller one into it, luted them well together, and exposed them to the Heat of the Sun, from the tenth of *May* to the tenth of *July*. I then distill'd this Liquor in a Retort with a gentle Fire, till there remained at the bottom a thick pinguious Liquid, that appeared like a thinner kind of an Oil, in which there were hard Chrystals of Sea-salt. When this was done, I poured the distilled Liquor back again, and repeated this three times, constantly drawing off the same quantity I put on; and at last there was left a spongy, oily, pinguious Salt at the bottom. This Operation I afterwards repeated with all possible care and accuracy for five and twenty times more, and then took what came off upon the last distillation, and poured it back again upon the *residuum*, and let them stand thus mixed together for five months. I then, with a very gentle Fire, drew off a Phlegm that was almost insipid, and when I perceived a very acid Spirit begin to rise, I fixed on another Receiver, and urging it with a little stronger Fire, there came over a very acrid, acid, heavy Oil of Salt. This I set aside by itself; and after all these distillations, the Salt that remained at the bottom of the Retort, was still very acid, and considerably fixed. This I then put into a glass Plate, and exposed it to the Air in a subterraneous place, where it run *per deliquium*. * When this

* It's pretty remarkable here, that our Author does not say that he actually did depurate this Liquor, &c. and then procure from it this noble Solvent; but says, when it is depurated, &c. such a one may be procured, and refers us to *Paracelsus*. Nor in the next sentence, tho' he says he took all this pains to learn whether what *Paracelsus* said was true, does he tell us whether it is so or no.

Liquor is afterwards depurated by filtration, and mixed again with the Phlegm, Spirit, and Oil of Salt, that came off first, there is produced, upon a new distillation, a Liquor of those solvent virtues, that fully answer all our trouble. *Vide Paracels. x. Archidox. C. 4.* I was willing, Gentlemen, to take all this pains, to learn, if I could, what truth there was in what *Paracelsus* had asserted. Mr. *Boyle*, after a proper and long protracted digestion, by a moderate sand heat, procured from Sea-Salt, without any thing mixed with it, a Spirit, without any Phlegm, and before any Phlegm arose. Nine parts of Sea-Salt being dissolved, filtered, depurated, and chrystallized, yield one part not to be formed into little Glebes, which is rough, austere, and saline: This being separated, the Salt becomes purer. *Du Hamel. Hist. de l'Ac. Roy. des Sc. p. 16, 17.* If a person then considers all these things, he won't wonder, that the greatest Masters have ascribed such extraordinary virtues to Sea Salt chemically prepared, both in *Menstruums*, and Medicines: Every one will see what method it ought to be prepared by.

Our Nitre, procured from animal substances, an Alkali, and Lime-Earth, and afterwards purified, hence easily becoming alcalescent, and fixed, and being as readily again convertible into a volatile Acid, is of a pretty singular nature, considered as it acts upon Bodies, as a *Menstruum*: And its operations, indeed, are often so intricate, that it is scarcely possible rightly to comprehend them; which happens chiefly from its being so mutable in the Fire itself, when it is mixed with other substances. If it is exposed to the Fire, pure and dry, as it so soon runs with other Bodies like Water itself, hence, though they otherwise would not melt without a great deal of difficulty, it wonderfully promotes the fluxing them, and attenuates, divides, and mixes them together, even though you suppose it to act here with no other virtue. For this reason, persons who are employed in fusing of Metals, make use of Nitre for forwarding their work. But in the second place, if there is any thing in the substances mixed with it of an oily, pinguious, sulphureous nature, this immediately, in a melting Fire, detonates with the Nitre, with a great *impetus*, takes fire, instantly excites a prodigious Heat, greatly raises the strength of the Fire, applies it more violently, and hence vastly changes, divides, melts, and separates Bodies, and in a very different manner from what can be effected by any other contrivance. But at the same time, the Nitre itself likewise loses the nature of Nitre, and acquires that of *Sal-Polybreft*, which has quite another dissolving power from what the Nitre had from which it was produced. Hence, therefore, there are three various actions of Nitre upon Bodies in the Fire; one before it deflagrates with them; a second during the time of deflagration; and a third when it is perfectly over. In the third place, when Nitre is melted with Vegetables that turn to a Coal, it then, likewise, is put into a very great motion, violently agitates and dissolves the solvent Bodies, and at the same time sends forth wonderful active Fumes, which being assisted by the Fire, penetrate, and dissolve every thing. And lastly, when it is thus converted into a fixed Alkali, it won't then melt without the strongest Fire, and has then acquired the quality of an acrid, penetrating Alkali, though always of a particular nature; and hence again it begins to act as a fixed, alkaline *Menstruum*, and thus obtains and exerts a new dissolving power: But this was treated of before in our History of alcalious *Menstruums*. In the fourth place, if the same Nitre fus'd

Salt of Nitre
a *Menstruum*.

with its solvend Bodies, happens to meet with any Earth, Stones, Alum, Vitriol, Brickduft, or the like, it is immediately converted into a very acid, volatile, sharp Salt, which being agitated with so great a Heat, penetrates, dissolves, and induces prodigious changes upon the Bodies it is mixed with, acting in this case like *Aqua Fortis*, with one part, whilst the other part that remains at the bottom acquires a new, and very different solvent power. Hence, therefore, we see how wonderfully efficacious this Salt must be, when it is used like a Cement with metalline Glebes; for then it is converted into such corrosive Spirits, which at the same time make great alterations in the Metals. But this I have sufficiently explained in our account of Acids, to which, therefore, give me leave to refer you. Again, in the fifth place, if pure Nitre is fused in an intense Fire, and is kept in the Fire with the reguline part of Antimony, it becomes a perfect caustic Stone, which acts in a manner that cannot, as I know of, be imitated by any other Salt: For this Salt is exceeding fixed, vastly difficult of fusion, and of an uncommon, igneous acrimony. Hence, therefore, it appears what a wonderful dissolving efficacy this Salt must have, when, together with *Regulus* of Antimony, it is applied to Bodies in the Fire. Sixthly, if upon Nitre, when it is in fusion in a clean Crucible in the Fire, you throw powder of *Sal-Ammoniac*, it will take fire in the same manner as if a live Coal was thrown into it, but somewhat softer; and it is by this means altered every moment, and becomes of another nature, 'till at last, being perfectly saturated, it will not take fire any longer upon throwing in of the *Sal-Ammoniac*, but is converted into a new kind of Salt, which at last grows reddish, is of a singular nature, though but little regarded or known amongst the Chemists. When Nitre and *Sal-Ammoniac*, therefore, are thus mixed together with other Bodies in the Fire, a different kind of solution will happen every moment, and consequently new effects will be continually produced, whilst these thus remain in the Fire together. To these things the Operators very seldom sufficiently attend, and hence it comes to pass, that they frequently meet with *Phænomena* they were not aware of, which disturb their Operations, and render the success of their Experiments uncertain. In the seventh place, if to the Solvend you add one ounce of Sea-Salt, and two ounces of Spirit of Nitre, or *Aqua Fortis*, the Liquor that is expell'd with a moderate heat will be an *Aqua Regia*, and act only with the power that that does; whilst the Salt that remains at the bottom will be Nitre. Hence, therefore, it appears, that in the latter part of the Operation, when it comes to be dry, it will act like true Nitre; whereas, at the beginning, the Liquor that was separated had the efficacy of *Aqua Regia*; and it is likewise as evident, how various the effects may be in different parts of the time that any given *Menstruum* continues in action. In the same manner if upon one part of very pure Nitre, you pour two of Spirit of Sea-Salt, they will yield in distillation a pure *Aqua Regia*, perfectly so in every property and very strong; but if you then increase your Fire, and proceed to distill to a perfect dryness, you will find again at the bottom of the Retort a true Nitre in all respects. Hence, therefore, we see how cautious we ought to be, that we are not deceived in our *Menstruums*. And again, if Spirit of Nitre, and a proper quantity of any Alkali are mixed together, with the solvend Bodies, they soon return into a Nitre, and therefore act like a Nitre in the last part of their Operation. And if what *Glauber* says is true, that Sea-Salt, a fixed Alkali, and

and Quick-Lime, mixed together, and ustulated till they are red hot, and then exposed to the Air, and thence moisten'd, will produce a true Nitre, then certainly if these materials are made use of together in cements, they would have a very different effect from what one would at first imagine. These things, then, if a person rightly considers, and at the same time adds what we have already said of the conversion of Nitre into an Alkali, in our History of alkalious *Menstruums*, and into an Acid, in our account of acid ones, he will sufficiently understand its efficacious and various dissolving power.

Native Borax, the produce of the *East-Indies*, *Persia*, and *Transylvania*, being dissolved in Water, filtered, and chrySTALLIZED, is of a bitter sweetish taste, and neither acid, nor alkalious. In distillation it yields a mere Water, and a Glass; which Glass may be afterwards dissolved in Water. If it is mixed with Sand, and urged with the strongest heat, it affords no acid Spirit. It exceedingly promotes the fluxing of Metals, and by thus fusing them, unites them thoroughly together, and by this means produces many effects which could not be accomplished in another way, without a great deal of difficulty.

Borax as a
Menstruum.

Whoever, now, is properly acquainted with what we have delivered concerning saline *Menstruums*, will readily conceive, how, by the various combinations of these Salts with one another, may be produced a vast number of new saline *Menstruums*, every one of which will presently acquire new and different dissolving virtues. This composition, now, is sometimes effected by art, and with design; at others, it happens accidentally, and without being foreseen, and so comes to be reduced among other chemical observations. And from these two fountains have there risen a vast quantity of *Menstruums* which have been described by the Chemists. Thus, for instance, if volatile Alkali's are united with fixed ones, then the volatile, by the action of the Fire, are always rendered stronger, harder, and more volatile; whilst, on the other hand, the fixed attracting the Acid, perhaps, from the volatile, as likewise the Oil, and Earth, become always differently compounded, and have not the same efficacy they had before. Fixed Alkali's, mixed with native, vegetable Acids, produce a wonderful compound Salt, which is soft, aperient, and diuretic: This we see in *Omphacium*, or Juice of Lemons, or the like, mixed with a proper proportion of Salt of Wormwood; for the Salt arising hence has very different solvent powers from what the Principles have from which it is made, or than any other Salts have. If you mix volatile Alkali's with these Acids, you have then another compound Salt, as different as possible from the former with the fixed ones. If you rightly combine fixed Alkali's with pure, fermented, vegetable Acids, you procure, after many surprising *Phænomena*, a saturated Salt, which is volatile, soft, penetrating, saponaceous, melts easily in the Fire, and possesses very extraordinary virtues. Here the Vinegar returns into its proper *Matrix*, Salt of Tartar, and impregnates it with its own peculiar Acid, which was acetose; for the Chemists call Vinegar fluid Tartar; and hence they have given to this Salt the name of regenerated Tartar. Others have called the Mixture prepared in this manner (*Acetum radicum*) radicated Vinegar; as it appeared to return into its proper (*Radix*) Root. And having myself often experienced the beautiful effect of this Salt, both in the animal, vegetable, and fossil Kingdom, I have been in doubt, whether this is not in reality the *Sal Tartari Volatilis* of *Helmont*, which the author so highly extoll'd for its virtues. Be this as it will,
this

Compound,
saline *Men-*
struums.

this I can safely affirm, that in the whole class of *Menstruums* there is scarcely one that deserves examination, and application, better than this does. This I could make appear by an infinite number of examples; but let one suffice. That noble Gum, Myrrh, cannot, without a vast deal of difficulty, be so dissolved by Alkali's, or Acids, as to be rendered subtil enough to penetrate into our Veins, if it is taken into the stomach; but if you digest it according to art with this Salt, it melts, and in an inimitable manner dissolves into a thick, homogeneous, medicinal Mass. This Salt, if it is made very accurately, will very intimately unite with Alcohol of Wine, and thus yield a *Menstruum*, which no person will repent making, though it costs him a great deal of pains. Hence, therefore, we see how much some of the more modern Chemists are in the wrong, who, making Alkali's and Acids the grand principles of Bodies, assert, that these can't be mixed together with any propriety, nor without acting contrary to true chemical knowledge, intimating, that by this means the noble virtues of the Alkali's are destroyed by the Acid, and what remains is of no efficacy, as *Zwelfer* in his works so often inculcates. But these Gentlemen may know, that if the purest Alkali of Tartar is united, according to art, with the volatile Acid of Tartar converted into Vinegar by a double fermentation, then the Alkali, and its proper virtue, being destroyed, as well as the Acid of the Vinegar, and its proper virtue, there arises a new neutral Salt, the efficacy of which is much more excellent than that of either the Alkali, or the Acid. And when a pure volatile Alkali is accurately combin'd with a very pure, strong Spirit of Wine Vinegar, so that you nicely obtain the very point of saturation, you have then a limpid Liquor, very little Salt, without any remarkable acrimony or smell, considerably volatile, and compounded of the lightest Alkali and Acid. And this possesses a very peculiar, dissolving power, which in vain you will seek any where else; for it is capable of penetrating into almost all kinds of Bodies, and resolving them without any great apparent agitation. Hence the Physicians have valued this Water exceedingly for removing diseases of the eyes and ears, arising from any preternatural concretions. And for the same reason, among all the secrets for discussing, and resolving glandular tumours, nothing hardly is found more efficacious than fomentations with putrified Urine and Vinegar, if the part is first well rubb'd, and they are then applied hot. From these observations, now, we may likewise understand, what will be the consequence of combining fixed or volatile Alkali's with fermenting Acids; for at first they will cause a sudden effervescence, then put a stop to the fermentation that was begun, and produce Salts, very much resembling those that have been described. And the same kind of Salts are produced, likewise, by mixing Alkali's with those Acids that are separated from Vegetables, whilst they are burning, or with those that are drawn from them by distillation. But if you combine fixed Alkali's with the native Acid of Fossils, there then again arise new Salts, but those vastly different too from one another. If, for instance, you dissolve the purest Alum in clean Water, and heat it, and drop into it hot Oil of Tartar *per Deliquium*, 'till it is perfectly saturated, they will precipitate a chalky *Calx*, and the limpid Liquor swimming at top, and consisting of the native Acid of the Alum attracted into the Alkali, being defæcated, and filtered, will yield a Salt like *Tartarus Vitriolatus*, but free from any suspicion of a metalline taint, whose virtues are excellent in Chemistry as a *Menstruum*, and are very efficacious

cacious in medicine. In the same manner, if you take either the white, blue, or green Vitriol, and dissolve it in four times its weight of Water, filter it, and drop into it hot, a fixed, hot Alkali, till you come to the point of saturation, you will thus again have a compound Salt arising from the Alkali, attracting into it the Acid which had corroded the Copper, or Iron, in the Mines: So that here again you have a natural, vitriolated Tartar, which differs from the common, in this particular, that its Acid has not been exposed to so strong a Fire, and hence has more beautifully retained its natural virtues: And besides, it will more perfectly deposit its metalline parts, except it be the true *Calcanthum* of Copper, for then, indeed, part of the Metal remaining in the solution, will discover itself in the Salt, by a blue colour. But farther, whenever you intimately mix a fixed Alkali with any true Sulphur, then the fossil Acid is attracted into the fixed Alkali, and if nothing else prevented it, there would be produced a Salt like the former: But we find, however, that it is in some measure of another nature, as appears from the saline *Spicula* that are formed from it. And this seems to happen, because the pinguious, oily Matter, which is mixed with the Sulphur, unites itself with the fixed Alkali, as well as the acid does, and thus prevents the pure saline parts concreting together, and by its interposition forms a decompound Salt, of a very different smell, taste, and efficacy. From what has been said, then, it appears what will be the consequence of mixing Vitriolic, or Alum Waters, or their inspissated, pinguious *Residuums*, by what name soever distinguished, with these fixed Alkali's; for by this means the metalline and terrestrial part, which these contained in them, will be separated, and the solvent Acid will unite with the Alkali into a vitriolated Tartar, whose dissolving Power will be singular, and different from that of all other Salts: This the application of it to Metals, Semi-metals, Sulphurs, and other fossil Glebes generally evinces. And it commonly too retains its virtues longer without alteration, than any other compound Salt; for it has its Acid more strongly combined with a very fixed Alkali, into an exceeding fixed Salt: Nor is there any known Acid in Nature, which, if poured upon vitriolated Tartar, is able to dislodge the Acid that is united with it, though the native Acid of Vitriol expels the Acids from all other compound Salts, as has already appeared. But on the other Hand, if with native, fossil Acids you mix pure, volatile, alkaline Salts, there then arise particular kinds of *Sal-Ammoniac*; and as these are compounded of a fossil Acid, and a volatile Alkali, perhaps, for distinction sake, they may be, not improperly, called Semi-volatile, vitriolated Tartars. And these, likewise, deserve to be well considered by the Chemists among their *Menstruums*, on account of their remarkable dissolving power; and by the Physicians for their noble efficacy in opening, attenuating, resolving, and stimulating. What then will be the effect of mixing common *Sal-Ammoniac* with Vitriols, and then exposing them to the Fire? Why, the Acid of the Vitriol being attracted into the alkaline part of the *Sal-Ammoniac* will expell thence the acid Spirit of the other part of the *Sal-Ammoniac*, render it volatile, and separate it, and then from the conjunction of the Acid of the Vitriol, and the Alkali of the *Sal-Ammoniac*, there will be produced a semi-volatile, vitriolated Tartar, such as was just now described, and the remainder will be a metalline Mass, which existing before in the
Vitriol,

Vitriol, is now precipitated from it, and separated in the Form of *Fæces*, or, being again corroded by the Spirit of the Salt, produces a new kind of dissolved Metal. Hence, then, you have a true method of judging what will be the consequence of combining fixed or volatile Alkali's, with all native, fossil Acids, though these often lie very closely concealed in Metals, Earths, Oils, and other Salts; for the effect will be always the same, and for this reason may be foretold. And, indeed, these Experiments are so certain, and hence so entertaining, that they cannot be recommended too much; especially if we consider at the same time, that they are of excellent service both to Chemistry and Physic.

But before we quit this doctrine of *Menstruums*, it is necessary we should take likewise into consideration those *Menstruums* which are produced by the combination of fixed Alkali's with the fossil Acid procured by Fire. A pure, fixed Alkali, therefore, when it is perfectly saturated with the Acid of Sea-Salt, Fountain Salt, or *Sal-Gem*, gives a regenerated Salt, which resembles true Sea-Salt in almost every quality. If it is saturated with Spirit of Nitre, it forms a Salt that in almost every character resembles Nitre. If it is properly united with the Acid of Alum, burning Sulphur, or Vitriol, it makes the *Tartarus Vitriolatus* before described. On the other Hand, when a pure volatile Alkali is in the same manner combin'd with Spirit of Sea-Salt, *Sal-Gem*, or Fountain Salt, there then arises the genuine common *Sal-Ammoniac*. If it is united with Spirit of Nitre, or *Aqua Fortis*, it produces a semi-volatile Nitre. If with the acid Spirit of Alum, burning Sulphur, or Vitriol, it gives a semi-volatile, vitriolated Tartar, the same which we above described. These things then evidently inform the Chemist, how many, and what surprizing actions may be often excited in *Menstruums*, purely from mixing and uniting certain Bodies together, and then exposing them to the Fire, as a common moving cause; for it's incredible, what a prodigious alteration often arises from the accidental or designed addition, but of one single Body. And yet without an accurate knowledge of all these things, the chemical Doctrine of *Menstruums* will never be compleat. The Experiments I have made to inform myself in this matter have given me a great deal of Pleasure, as it does now to communicate the success of them to you. But there still remain to be considered the actions of those *Menstruums* where pure simple Salts are united with others. But this, from what has been already laid down, is almost evident of itself. If a pure Alkali is united with Sea-Salt dissolved in Water, the Brine grows turbid, an Earth is precipitated, and the Salt then properly procured by chrySTALLIZATION, is a pure Sea-Salt. A fixed Alkali put into a *Lixivium* of Nitre, makes it turbid and whitish, precipitates an Earth, and produces the most pure Nitre we know of. The same mixed with the Brine of *Sal-Ammoniac* attracts its Acid, by this means sets free its Alkali, expells it, and at the bottom produces a pure, fixed Sea-Salt, the volatile Alkali being dissipated into the Air. A pure, volatile Alkali put into a Brine of Sea-Salt, makes it turbid, depurates the Salt, and then flies off. If it is mixed with dissolved Nitre, it does the same, and purifies the Nitre. If you put it into *Sal-Ammoniac* well diluted with Water, it effects the same depuration there likewise, but it does not at all alter the nature of the *Sal-Ammoniac*, which continues exactly of the same vertue it was before. Vegetable Acids mixed with

with Sea Salt, Nitre, and *Sal-Ammoniac*, make but little alteration in them. And the same Acids, fermented, or rendered purer by distillation, mixed with the same Salts, don't change them a great deal. What alterations are produced in *Menstruums* by the artificial mixture of fossil Acids, with the Salts just mentioned, I gave you before, when I treated of those Acids and these native Salts. In a very few Words, therefore, I just repeat, that in Alum and Vitriol calcined to a dryness, there remains a good deal of a fixed Acid, which is exceeding strong, and has this peculiar property, that when it is rendered active by the Fire, it will expell all other Acids from any Bodies that were dissolved by those Acids, provided those Bodies are of such a nature, that they may be dissolved by this Acid of Alum, Vitriol, and Sulphur; and by this means it produces very particular effects, as a Solvent. Give me leave to illustrate this by an Example. Take Vitriol calcined to a dryness, rub it with Sea Salt, and put them together into a Retort, and with a Fire gradually increased to the greatest degree, distill them, and there will rise a pure Spirit of Sea Salt: For the Acid of the Colcothar being superiour, expells the volatile Acid of the Sea Salt, takes possession of the other fixed part of this Salt, and from these two concreted together, produces a kind of *Sal Mirabilis Glauberi*, but which, at the same time, contains the metalline *Fæces* that were in the Vitriol. But this, indeed, I explained to you before. Again, if you take Mercury, and rub it with calcined Vitriol, 'till it is thoroughly divided, and then to this Mixture add decrepitated Sea Salt, and put this Compound into a Glass Cucurbit, and very gradually urge it with a sand heat, then the Acid of the Vitriol converts the Acid of the Sea Salt into a Spirit, which being agitated and heated, dissolves the Mercury, as usual, and then carries it up in form of a pure *Mercurius Sublimatus*; which is nothing else but the very pure Spirit of the Sea Salt, attracted into the Mercury, and united with it into a homogeneous, vitriolic, mercurial Mass. But there are an infinite number of effects, and those very surprizing ones too, that may be understood from these principles in the History of *Menstruums*. Hence, from Alum, or Vitriol, calcined, and mixed with Nitre, is distilled *Aqua Fortis*, in which there is nothing of the Acid of the Vitriol, but which is pure Spirit of Nitre. If they are treated in the same manner with Sea Salt, you have a Spirit of Salt. If with Nitre and Sea Salt together, in distillation there arises an *Aqua Regia*. Hence, if Nitre and Colcothar are exposed to an open Fire in a Crucible, the Acid of the Nitre is dissipated, and there remains a kind of *Nitrum Vitriolatum*. And Sea Salt calcined in this manner, leaves a kind of *Sal Mirabilis Glauberi*. But it will be more entertaining to you, from the principles I have laid down, to carry these Experiments farther yourselves, than if I should lay them before you too particularly. I have but one thing more, therefore, to add, and that is, that by combining Salts with Salts in any manner whatsoever, there always arise new Salts, and new *Menstruums*. By this means, therefore, the Chemical Science is continually advanced; and hence now, appearances perpetually offer themselves to our observation, which are very agreeable, promote the knowledge of natural Philosophy, and often furnish us with new and very useful discoveries.

But in the last place, there arise new *Menstruums*, likewise, and those of different virtues, from the combination of various *Menstruums* with one another: And

here there is room for infinite application ; as there is also in reducing of any sort of *Menstruum* to its greatest purity ; and the attenuating any one into the least Particles, which it is possible either for art or nature to reduce it to : For in these three particulars seem to have consisted the peculiar and excellent knowledge of the top Masters of the Art. But it's impossible to deliver here what might be said upon this Head : Let one Example suffice. I want, for instance, the purest, strongest, and most subtil, vegetable Acid. Take, then, the best Verdegreafe, which is Copper finely corroded by a fermenting, exhaling Acid, and pour upon it twenty times as much of the strongest Spirit of Vinegar that can be procured by distillation : Digest these, that the Verdegreafe may be dissolved into a very green Liquor, which depurate accurately by letting it stand quiet, and filtering it, and then with a gentle Fire inspissate it till a pellicle is formed on the surface : Then let it be set by in a quiet place, and it will shoot into Chrystals, like Emeralds, consisting of the Acid of the Vinegar, and the corroded substance of the Copper. Decant the Liquor, collect the Copper Globules, and inspissate the Liquor again to a pellicle. Take out again the new-formed Chrystals, and proceed in this manner, 'till no more Chrystals appear. If you then dry this Copper Mould, thus saturated with the Acid, very gently with a moderate warmth of the Air, and then very gradually urge it in a glass Retort, you will have an incorruptible, vegetable Acid, exceeding strong, nor affected with any metalline taint from the Copper. If you attempt this with Lead, Tin, or Iron, it will never succeed : Copper only answers the end, by attracting the Acid, separating it from its Water, and returning it back again, without any alteration ; whereas the others attract it indeed, and separate it, but never part with it again pure. As from malt Liquor, now, fermented Manna, Honey, Sugar, Cyder, and Perry, such Vinegar may be prepared, from these, likewise, by the help of Copper, may be procured such a strong Acid. Hence *Zwelfer* falsely imagined, that he was in possession of the famous Alcahest, for which he was sharply handled by the shrewd *Tachenius*, who strenuously insisted upon it, that it was nothing but strong Vinegar. But there are infinite numbers of *Menstruums* that may be still found out : And hence almost every Artist boasts of some particular *Arcanum* ; nay, and indeed is able generally by the assistance of it, to do something more than any body else can possibly do, who is not acquainted with it. But here, it's true, the usefulness of the discovery is often not so much to be extoll'd, as the vanity of the possessor of the secret is to be blamed ; as no body who is expert in the art will ever be at a loss to find out new *Menstruums*, if after that he has by his art prepared Bodies, he will but apply them to others. And hence, perhaps, the Solvents proper to every kind of Body, and therefore to the human *Calculus*, might by this time have been discovered, if the Chemists had but applied all their Liquors to this Stone, as there are often effects produced in this manner, which could not possibly be foreseen : Thus, if a person was acquainted with all *Menstruums* whatever but Spirit of Bread, the efficacy of that in dissolving many Bodies would appear to him quite incredible. But by mixing one *Menstruum* with another, there often arise new ones, and those too very beautiful. Thus, for instance, *Tartarus regeneratus*, if it is rightly prepared, may be intimately united with the purest Alcohol of Wine ; and then you have a vegetable *Menstruum* composed of

of a vegetable Alkali, Acid, and Sulphur, exceeding subtil, and very closely combined together; and hence it is of mighty efficacy, made use of either as a *Menstruum*, or a Medicine. Again, if the purest, most saturated, alkaline Spirit is united with the purest Alcohol, it becomes the *Offa Helmontiana*, and makes a noble *Menstruum*. This very nicely dissolves distilled, vegetable Oils, and hence arises a *Menstruum* consisting of a genuine Sulphur and Alkali, concerning which one may doubt, whether there is any thing more excellent, either in Medicine or Chemistry. In the same manner, if the best Spirit of Nitre is perfectly saturated with an alkaline Spirit of *Sal-Ammoniac*, we obtain an almost volatile Salt of Nitre; and hence may be prepared that so much wished for volatile Nitre, which whether or no it answers the great Expectations formed of it, may then be easily tried by Experiments. In the cultivating and improving of these studies some Chemists have employed an Age, and have thought the pleasures that arose upon their new discoveries a sufficient recompense for all their labour. And let me advise you, Gentlemen, to apply yourselves to these inquiries, noting down whatever new you meet with, that thus, from a sufficient number of Observations collected together, you may, at last, with caution, be able to draw some Rules that shall be of a more general nature.

The doctrine of *Menstruums*, then, being thus dispatched, let us proceed Corollaries. to deduce some Corollaries from what has been delivered. First, then, it is not yet certain, whether any *Menstruum* has such an innate power, that it is able to act upon its solvend object without the least assistance of Fire. Nor, indeed, is it possible to make any Experiment that shall be able to determine this, as in every place there is Fire, and that a pretty deal too, from which it cannot possibly be freed. Nay, in fact, almost all the *Menstruums* that we are at present acquainted with, if they are quickned with a certain degree of Heat, perform their Solution so much the better. 2. *Menstruums* scarcely become efficacious, 'till they are reduced to a fluid form, or one very near it. And this, Fire, Air, Water, and Attrition, in particular, bring about; which four causes likewise generally excite *Menstruums* into action, though before they lay quiet. 3. Some *Menstruums* seem to have a power implanted in them, by the efficacy of which they produce a motion, depending only upon the nearness of the Bodies to which this motion relates. If a very good Loadstone, suspended by a Thread and at rest with respect to its poles and those of the World, should be absolutely without motion, one would be led to think, that it had no active power: But if in the very greatest degree of cold, a piece of Iron, or another Loadstone should be brought within the sphere of its activity, there would immediately be generated a motion in them both, which would last till they came into contact, and then being joined together, they would both be at rest. This power, therefore, spontaneously, and without the assistance of any sensible Fire, generates motion, not seeming to be excited by motion, itself. In the same manner, the best Spirit of Nitre, though it's kept close stopp'd up, will for years continue to emit a red Fume, which hanging over the surface, keeps in continual motion, and rises out of the mouth of the Vessel as soon as ever you take out the Stopper. The same thing is true, likewise, in an alkaline Spirit of *Sal-Ammoniac*, which, as far as I have been able to observe, is never at rest. And as for that Spirit which is distilled from *Sal-*

Ammoniac, with Quick-Lime, that is still much more agile. Such Bodies, therefore, both excite and preserve motion in a wonderful manner. That such Vapours, now, may be perpetually floating about in the subterraneous parts of the Earth, 'till they light on some certain Bodies, in which being afterwards fixed, and united, they form variety of compound Bodies there, who will deny? In all these cases, however, this must be considered, that even in the greatest degree of Cold, the Air is in a constant oscillatory motion, which is often the cause by which those motions are likewise excited. By this motion, now, proper to *Menstruums*, and arising from them, solutions are often brought about immediately, which could not be effected by the greatest degree of motion excited by any other cause. If you have a mind to see an instance of this, take only a piece of *English Chalk*; let it be calcin'd in the intensest Fire, nay, even *Tschernhausen's Focus*, and it will scarcely be altered in this vast motion; expose it to the hottest, coldest, calmest, or most stormy Air, and it will remain just the same; keep it ever so long in boiling Water, it will not be dissolved; boil it in a *lixivium* of Salt of Tartar, and it will still be chalk: And yet put it only into cold Vinegar, and it will dissolve and disappear. Hence, therefore, it is evident, what a prodigious difference there is between that motion which is excited by the reciprocal action of the *Menstruum*, and Solvend, and that which is produced by Fire, Air, Water, and Impulse. 4. That which we call acrimony, therefore, in a *Menstruum*, because it corrodes our Body, and gives us pain, does not render such a *Menstruum* fit to dissolve other Bodies: This we see evidently in Oil of Vitriol, Spirit of Nitre, Spirit of Salt, and *Aqua Regia*, which though they instantly consume any part of us, are not capable of dissolving Wax, and Sulphur, which are so easily dissolved by our Humours. 5. Many *Menstruums* cannot naturally dissolve certain Bodies; and yet if these Bodies are first dissolved in some other *Menstruum*, they will then be disposed to be dissolved in those very *Menstruums*, which before they absolutely resisted. Boil, for instance, common Sulphur in Alcohol, as long as you please, and it will no more dissolve in it, than a Stone will in Water; but melt this Sulphur with Salt of Tartar, and it becomes a redish brown Mass, and then pour Water upon this, even in the cold, and the Sulphur will be very readily and intimately dissolved: Boil Powder of Antimony in Alcohol, and it has no effect upon it; but boil the same in an alkaline Salt dissolved *per Deliquium*, till it becomes a dry Mass, and then pour Alcohol upon it, and you will soon have a golden Tincture. And, indeed, such a well-managed, successive application of different *Menstruums* to Bodies, the greatest Masters in the Art have laid so much stress upon, that *Boyle*, *Homborg*, and *Tachenius* have told us, that even Metals themselves may by this means be intimately resolved into their two constituent Principles, a fixing Sulphur, and a regenerated Mercury. For they assert, that if Silver is dissolved in Spirit of Nitre, and then digested for a long time in a pure, fixed Alkali, and afterwards sublimed a good many times with *Sal-Ammoniac*, it will at last yield a fluid Mercury; and at the same time they call these, resuscitating Salts. Thus Acids procure an entrance for fixed Alkali's into the inmost parts of Metals; and then the fixed Alkali's assist the volatile, alkaline Salts to penetrate them, which otherwise they had not been able to effect. This is what these Gentlemen assure us. If you ask me whether

I believe

I believe that Metals may thus, by the assistance of Salts, be reduced to Mercury? I can't tell what to say to it. For my own part, I frankly confess, I have taken a great deal of pains upon this head, but have never yet been able to effect any such thing: Conscious, however, of my own inferior abilities, I would by no means go about to detract from the capacity or credit of others. 6. Some *Menstruums* dissolve certain Bodies, which before the Experiment was made, seem'd the least in the World fitted for such a solution, whether you regard either the *Menstruums*, or the solvend Bodies. Thus, for instance, the tenacious, viscid, native Turpentine becomes so penetrating in the human Body, that in a very short time it gives a violet smell to the Urine, changes its colour, and heats the whole Body; if it is mixed with Oils, it dissolves them; as it does perfectly Resins in a small degree of Heat, tho' they dissolve with so much difficulty: And it has the same effect, likewise, upon Gum-Resins, which can scarcely be dissolved by any other method; as Gum-Copal, and others. But what must we think, again, of the Yolk of an Egg? If one may be allowed to speak by analogy, it is the *Placenta* of the Chicken, an organical Machine, whose infinitely subtil structure eludes the most acute, microscopical observation, and the most curious anatomical inquiry. Is it not a viscid, tenacious, unactive Substance, without Smell, taste, or any the least degree of Acrimony? And yet if this is rubbed in a gentle Heat, according to art, with any gummy, oily, resinous, or balsamic Substances whatever, it does more than can be effected by any other *Menstruum*; for it destroys their viscidness, and renders them dissoluble in Water, and Spirits, and very easily miscible with the animal juices. Here then we must allow, that Nature furnishes us with a *Menstruum*, that can scarcely be equall'd by any production of the profoundest Art. The very bitter, yellow Bile too of any sound Animal, Fishes in particular, that have no Lungs, and are voracious, have almost the same effect upon balsamic, gummy, resinous, tenacious, teribinthenaceous, viscid Substances, which they happily dissolve by being gently mixed with them. Manna, Honey, and Sugar, with warmth and rubbing do the same. I might here take notice, likewise, of the White of an Egg: When this is hardened by boiling, well separated from the Yolk, and distilled in a *Balneo Mariæ*, it yields a clear Water, that has no considerable Smell, or Taste, is neither saline, acid, or alcalious, and yet whose efficacy is so great and peculiar upon Metals, that both *Paracelsus* and *Van Helmont* agreed, that this alone was proper for the preparation of their medicated Mercury, of such excellent virtues. And if you take the hard White of an Egg, put it in a clean Vessel, and in a Cellar expose it to the Air, you will have from it a very insipid Liquor, which, if it was offered one, one would take to be pure Water; and yet this Water will penetrate Myrrh, which is so hard to be dissolved, in such a manner, that it will be better resolved by this, than by any other *Menstruum* whatsoever. To persons, now, not acquainted with these things, there is nothing seems more surprizing, than that Bodies should be dissolved by the very softest *Menstruums*, which are affected by scarcely any other. 7. I assert, therefore, that neither acidity, a lixivious acrimony, or saline disposition appearing physically to be present in any *Menstruums*, does ever demonstrate, *a priori*, that such a *Menstruum* will dissolve any given Body; but this certainty must always depend upon some Experiment, by which it

it has appeared that this Solution will happen, if this *Menstruum* and that Body are mixed together. For if simple Sulphur is put into any known Acid whatever, from the mildest to the strongest, even tho' it is assisted by Fire, the Sulphur will remain unaltered as Sand in Water. So Spirit of Nitre, howsoever it acts upon other Metals, has no effect upon Gold. It is idle, therefore, to say in general, that Acids dissolve Metals; for this or that Acid only, dissolve such and such particular Metals. If a Person, after he had in many instances experienced the corroding quality of the strongest caustic Alkali, should hence begin to believe that this power would extend itself to all other Bodies; how much would he be deceived, when he saw plainly that Mercury, Gold, and Silver, suffered nothing from this Solvent. And the same thing we observe holds good in Salts: For if Silver is boiled with Salt of Tartar it grows white, tho' it does not do so at all if it is boiled with Sea-salt. We must not therefore, pretend to say, that Alkali's, Acids, or saline Bodies, are solvents in general, but only in a limited sense, with respect to their particular objects: If we offer to proceed any farther, the nature of the thing is against us. 8. On the other hand, a prudent Chemist would not presently conclude, from seeing any Body dissolved, that the cause of this Solution, was an acid, alcalious, or saline Body, if there were not some other circumstances, that might more certainly determine it. And yet this error, the modern Chemists have often fallen into, who, being too prone to run into generals, have from any observed Solution presently imagined, that they knew the Solvent. But suppose, now, that in a given case, a Person was sure that Gold was there dissolved into its smallest Particles, and at the same time knew perfectly well that Gold is not dissoluble by any known Salt except Sea-salt, and what is produced from it: Yet even here, one cou'd not certainly conclude, that because Gold was here dissolved, therefore Sea-salt was the Solvent; for if the purest Mercury is rubbed upon the cleanest Gold, it will penetrate, corrupt, and dissolve it. In all nature, now, we don't know any Body, that is less acid, alcalious, or saline than Mercury; no Body in which there is less Acrimony than in this, as it gives no pain, tho' it is applied to the Eye, or the bare Nerves: And yet this we see dissolves Gold, which Sea-salt excepted, resists every acid, alcalious, saline, acrid Body that we are acquainted with. 9. But I assert farther, which is still a greater paradox, that all that physical Power, which we generally call corrosion, or corroding Acrimony, is, absolutely considered, nothing at all, but relative only between particular corrodents and corrodends, and not between every corrodent and all other Bodies: Hence, if a Person, after he had, in an infinite number of instances, experienced the corrosive Acrimony of *Aqua Fortis* upon Animals, Vegetables, and Fossils, shou'd thence hastily conclude, that therefore this very corrosive Liquid wou'd much easier corrode any Bodies that were softer, he wou'd soon find himself mistaken by putting into it the softest Wax, or the brittlest Sulphur. 10. Nor, on the contrary, will it at all follow, that because any particular Body is very soft, with regard to our senses, nor corrodes and resolves the Animal Fibres, it has not, therefore, a dissolving Power: For a Person, without any inconvenience, might take a considerable quantity of sweet Oil of Olives; and yet Sulphur, which resists every corroding Acid, may soon be entirely dissolved in it; as may Wax likewise, which corrosive Acids do not affect. Even melted Wax, which is so soft and unactive, is said to extract a

Colour

Colour from Coral, gently indeed, but very efficaciously; and yet the same Coral would bear the extreme violence of the Fire for a long time, without being altered; nor be affected by any Alkali's. This no-body could easily have believed *a priori*, but must first be convinced of the truth of it by particular Experiments. Those Bodies, therefore, which appear to us to be exceeding hard, and are found to be so in the Fire, do not hence, in order to their Solution, require Solvents which have given any proofs of their being very acrid. And hence, upon these principles, it won't seem impossible to be found out in Art or Nature, a Solvent that shall be suited to any given Body scarcely dissoluble by any thing else, which *Menstruum* at the same time shall not be able to corrode other Bodies, that are much weaker and softer. And the only way here, if one would do any good, is successively to apply all the *Menstruums* we know of, to the Body whose Solvent we want to discover: For very often that which seems most unfit for the purpose, answers it better than any other whatsoever. Consider, for instance, the Stone in the Bladder, and Cancers. These we have not hitherto been able to cure; but yet we ought by no means to despair of finding out a Remedy, which may be able to dissolve the Stone without hurting the Bladder, which from what has been said, we see wou'd not necessarily follow. Spirit of Rye-bread, has a wonderful power of dissolving almost any Stones, and yet does not by any corrosive quality hurt the human Body. The Water drawn from the hard Whites of Eggs, may be dropp'd into the Eye without any pain; and yet with regard to many things, has a dissolving virtue. 11. Most *Menstruums*, at the very same time that they dissolve, and change their objects, are perfectly likewise changed by them, so that the action between them is reciprocal. This appears to be true in almost all *Menstruums*. Water, Alcohol, and Mercury, indeed, are less altered than others, but those likewise are changed by degrees. For tho' the Alchemists say that the purest Mercury never suffers any alteration; yet this by the admixture of other Bodies is altered by concretion: And as that itself is often rendered impure by other Bodies, it must then be in some measure altered by them; even when by transmutation it is converted into Metals. 12. It is a very great mistake to imagine, that all *Menstruums* will constantly perform their Solutions so much the more efficaciously, as they are more depurated, and reduced to their greatest degree of strength; for very often their virtue decreases in proportion to their strength and simplicity. If you want, for instance, a Vitriol of Lead, and for this purpose dissolve it in *Aqua Fortis*, you will always find the Solution more difficult in very strong Spirit of Nitre, than if it is diluted with a sufficient quantity of Water. The same is true in Iron, which dissolves in Oil of Vitriol mixed with four times its weight of Water, whereas if it is thrown into the purest Oil of Vitriol, the Mass in an instant becomes almost immoveable. Hence the purest Alcohol coagulates a great many things which common Spirit of Wine dilutes and dissolves: This appears evident in human Blood, which is coagulated by the former, but diluted by the latter. Hence the greatest simplicity of a *Menstruum*, or its utmost perfection in its kind, does not always increase its dissolving power upon particular Bodies. But on the other hand, it is true likewise, that if the same *Menstruum* is applied to other Bodies, it often requires the exactest purity to be able to act upon them as a Solvent. If we want, for instance, to dissolve distilled Oils accurately in Spirit of Wine, it must

must first be reduced to the purest Alcohol, or it will have no effect at all. In the same manner, if you wou'd dissolve Amber in Spirit of Wine, you must make use of the most rectify'd Alcohol possible. So that here again we can't pretend to pronounce absolutely of *Menstruums*, whether they are required pure, or diluted, to induce such and such changes upon Bodies, unless it has been first precisely determined by Experiment. 13. But in this Doctrine of *Menstruums*, there is nothing more remarkable, than that in Solutions performed by them upon their object, there often arises a new power in Nature, which neither existed in the *Menstruum*, or Solvend, before the Solution, but depends intirely upon this union of them together. A Child, for instance, may without any inconvenience, take 3 grains of Crude Mercury, and so it may 7 or 8 grains of Spirit of Sea-salt; and yet when from these prepared together, you have 4 grains of *Mercurius sublimatus corrosivus*, if the Child should take this, it would prove a most violent Poison. So one may safely give a Child 30 grains of Crude Antimony powdered, and as many of Nitre properly diluted; but if these are reduced to a Powder, mixed together, and then set on fire, you have in an instant a *Crocus Metallorum*, of which no-body wou'd give a Child 6 grains, that did not design to destroy it. I wish, therefore, the Chemists wou'd hence be cautioned for the future, not to believe that the productions of their Solutions are always good Medicines, or at least not hurtful to the human Body, because the Simples which produced the Compound had medicinal vertues, or else were innocent. Certainly, the greatest miscarriages that have happened in the Art, and have often brought it under such disgrace, have risen from this precipitancy of the Artists. And, indeed, nothing has ever more surprized me, than to see the unlimited liberty that both the Chemists and Physicians have taken in determining the medicinal vertues of every Body which they have by their Art prepared. Examine *Basil Valentine* only, in his *Currus Triumphalis Antimonii*, and you will see a flagrant instance of it. For my own part, I have often thought with myself, that a Carpenter, Mason, or any other handicraft, might as well cry up every thing in their way, as these Persons do in theirs. But you, Gentlemen, who will make truth, and the good of mankind your study, will always remember, that this itch of commending every thing must be prudently restrained; and that if you shou'd meet with any new thing that you have a mind to make trial of, it is proper to begin with a very gentle dose, and proceed gradually, carefully attending to every effect it produces: And if it is made use of with this caution, the Doctrine of *Menstruums* will open a way to the understanding the most excellent things that belong to the Art. For if you examine the *Classes* we have described, and the Objects that properly belong to every one of them, and consider carefully the true marks assigned, you may then at length make use of this Doctrine in such a manner, as to be able, as much as possible, to determine *a priori*, what will happen upon the application of one Body to another: But here, however, you will continually meet with new appearances which you were not acquainted with before. As far as I have been able to let you into the Knowledge of these things, I have done it with pleasure, and must now pass on to something else, viz. the consideration of

The

The universal Menstruum or Alcahest.

Whoever, therefore, carefully considers what has been hitherto delivered, will easily believe, that all chemical solutions of Bodies, except a few purely mechanical ones, are the effect only of attraction, and repulsion, between the Particles of the *Menstruum* and those of the Body dissolved; hence, therefore, that all the action here depends upon the relation betwixt these two; and of consequence, that according to the known rules of art there cannot be assigned any Body, either natural, or artificial, which, without any distinction, would dissolve all Bodies whatsoever: Nay, and farther, that it is impossible to deliver any physical method, by which the resolution of all Bodies promiscuously may be obtained. Nevertheless, after *Van Helmont* the Father had published his Writings, there was a report went about in the Chemical World, of a secret, universal *Menstruum*, which *Paracelsus* was said to have possessed, and which he, according to his manner of writing, called the *Alcahest*. If any such thing, now, as *Helmont* solemnly swears, was ever known to any mortal, it certainly ought to be looked upon as the most excellent favour, that the Divine Being ever indulged Mankind with, either in the Chemical, or any other Art. This, without dispute, would be vastly more valuable than any Philosopher's Stone, and much more to be wished for, as by the help of it might easily be obtained the most certain means both of Health and Riches. This, with a great deal of reason, was the opinion of Mr. *Boyle*, who yet, after an infinite deal of Pains, and with all the skill that he by this means acquired, was never able to come at the discovery of it, nay, upon the best foundation, scarcely believed, that there ever, in reality, was any such thing. Designing Men, however, have made a handle of it to satisfy their avarice, by imposing upon such persons as they found fond of such kind of *Arcana*: Prudent Men have always remained in suspense, not daring absolutely to pronounce any thing in it. For these reasons, therefore, I was willing to give you an historical account of this Affair, just as it is, that is to say, as it may be collected from the Writings of those Authors who alone have wrote of this *Menstruum*; that thus at least we may know the opinion of those Persons, who tell us, they have possessed, and made use of this *Arcanum*. Every thing, however, that has been said upon this head, by other People, has been borrowed from *Helmont* alone; for from what *Paracelsus* himself wrote of the *Alcahest*, no mortal would ever have thought of any such thing, had not *Helmont* given the hint, that such great mysteries were couched under this uncommon Word. As for my part, I confess freely, I am not master of this secret of the Fire; and therefore I can do no more than by carefully examining, and faithfully comparing one thing with another, lay before you what is to be found in these Authors. And if these persons were really acquainted with any such thing, and were willing that one who studied their Writings attentively should find it out; I know no better way of coming at it than what I have proposed. By this means a person who is disposed to set about this grand work, may know what Matter he must make use of, by what Instruments he must operate, and in what method he must proceed, that so he may not lose both his labour and his money. And it will farther, too, have this great advantage, that it will secure us

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from

from being imposed upon by the tricks of Impostures, whose boldness and knavery make them formidable, but who don't know themselves what they pretend to; for these Fellows may be easily detected by any person who is acquainted with the doctrine of *Paracelsus*, and *Van Helmont*. This I myself have sometimes found excellent use in, when I have happened to have to do with these vain pretenders. Let us, therefore, with a great deal of caution, proceed.

First, the
Name.

And in the first place, let us consider the name, which is *Alcabeft*. This word, before *Paracelsus*, no body ever made use of, no not even among the Chemists. And even he himself, as far as I have been able to discover, never used it, but in one passage, which you have in his Treatise *de Viribus Membrorum*, Lib. II. C. 6. where there are these words. *And the Liquor of the Alcabeft is exceeding efficacious in the Liver, to comfort and strengthen it, and to preserve it from a Dropsy, and all the Diseases that have their rise in it. And its process is, to be resolved after Coagulation, and coagulated into a transmuted form. This appears in its process of Coagulation and Resolution. And then if it overcomes (sui simile) that which is like it, it is a Medicine for the Liver above all Medicines. Nay, though it were consumed, it would supply the place of an intire Liver, as though it were not consumed. All you, therefore, that make Physic your Study, ought to know how to prepare the Alcabeft, in order to remove a great many Diseases that have their seat in the Liver. So that Paracelsus never made use of this word but twice, and that only in this place; nor is there the least Mention of any such thing, either before or after, as I informed myself by a careful examination of all his works. No mortal, therefore, from what he said upon this head, would ever have thought of this grand secret, had not *Helmont* afterwards added his interpretation.*

Secondly, its
Etymology.

The derivation, therefore, of this new word, thus coined by *Paracelsus*, was examined into. And upon considering, that it was usual with him to conceal common words by the transposition of their letters, it was imagined that was the case here; though sometimes too he formed strange words by joining the beginnings of different words together. Thus when he would have you make use of (*Tartarus*) Tartar to resolve the *Saburra* in the Spleen, he says, take *Sutratar*. L. II. *de Vir. Membr.* C. 7. And again when for diseases proper to the Kidneys he prescribes Saffron, which from its golden Colour the Chemists called *Aroma Philosophorum*, he says, these Distempers are cured by *Aroph*. L. H. *de Viribus Membr.* C. 10. Hence, therefore, some persons have thought, that *Alcabeft* signified *alkali est. Rolfinc. Eph. Germ.* D. 12. Ann. VI. VII. p. 193; *Rulandus* in his Lexicon; and hence supposed that it has always an Alkali for its basis, which is then saturated with a proper Acid. Others have been of opinion, that it was called so *quasi Staltzgeist* because if the *Alcabeft* is the same with the *Circulatum*, they imagined it was made from Sea Salt, coagulated, resolved, and coagulated into a transmuted form. But again, others suspected, that it was called *Alcabeft*, *quasi Algeist*, or a perfectly pure simple Spirit: This they thought its process of coagulation, resolution, and coagulation, seem'd to teach us. And lastly, there is *Faber's* opinion, who says, it is a pure, mercurial, metalline Spirit, which is so united with its own proper Body, that hence two become one Body, that is inseparable, and indestructible. *Eph. Germ.* D. 11. Ann. 8. App. III. This, then, being

being all we can learn from the etymology, let us pass on to the synonymous terms, and see if by comparing them together we can get any farther light into it. *Paracelsus* himself has left us no synonymous name, but *Helmont* has a great many, and therefore these we will now examine. And in short we have no other assistance besides the authority of *Van Helmont* alone, who declares that the very same bottle was given likewise to him.

In the first place, then, he calls it simply, *Water*; telling us, p. 88. § 27. ^{Thirdly, the Synonyma's.} that he knew a *Water* which he must not discover, by the mediation of which all Vegetables might be transmuted into a distillable Liquor, without the least *Fæces* remaining at the bottom of the Vessel. And in the same place § 29. he says he mixed together a certain *Water*, and Coals made from Oak, in an equal quantity, and digested them with a bath heat in a Glass hermetically sealed. And there he calls the same a *thick Water*, whilst he writes § 28, that in the second Book only of the *Maccabees*, Chapter the first, there is mention made of a *thick Water*, which was a perpetual Fire, and perhaps not unlike his *Water*. And in another place he calls it a *solvent Water*, as p. 628, where he says, the Liquor *Alcabeft* is an immutable, *solvent Water*. But he came still nearer the matter, when with one word he called it (*Ignis-Aqua*) *Fire-Water*, for whilst p. 337. § 3. he is giving an allegorical account how he came by his knowledge, he pretends he received a bottle in which there was *Ignis-Aqua*, of one word only, a name perfectly simple, singular, indeclinable, inseparable, and immortal. And again he calls it a *Latex* reduced to its least Atoms possible in nature. p. 94. § 28. But he very frequently calls it a *Liquor*, p. 85. § 6. By the addition of the *Liquor Alcabeft* of *Paracelsus*, he asserts, that all Bodies may be converted into *Water*, p. 119. § 89. And that by the *infernal Fire*, which is the *Liquor Alcabeft* of *Paracelsus*, may be known how much any Vegetable contains of either Luminary. p. 265. § 11. p. 384. § 43. p. 419, 628, 700. § 23, 700, § 2. p. 706. § 10. 714. § 27. 776. § 11. 60. And he calls it, likewise, the *solvent Liquor* p. 88. § 29. All these things, therefore, seem to intimate, that this *Arcanum* was of a moist, liquid form, like a kind of a *Water*. In another place, as a synonymous term, he makes use of *the Fire of Hell*; for he says expressly, § 28. p. 119. by the *Fire of Hell*, which is the *Liquor Alcabeft* of *Paracelsus*. And again, p. 45, 15. Original Sand resists both Art and Nature, nor can by any means be made to recede from its constancy, except by an artificial, *infernal Fire* alone, in which artificial Fire Sand becomes Salt. If *Helmont*, therefore, in this appellation has followed *Paracelsus*, by this we may know what the *Alcabeft* was, because *Paracelsus* himself has wrote of this *infernal Fire*: But of this by and by, when we come to speak of the *Alcabeft* itself. Afterwards, *Helmont* says, this is a most happy and perfect Salt, which has arrived to the utmost degree of purity and subtlety that Nature is capable of. § 24. p. 384. And for this reason, he seems to call it, the *Ens primum Salium*, p. 419; the *Sal Circulatus*, and the *Sal Circulatus Paracelsi*, § 11. p. 43. § 49. p. 374; the *Circulatum majus*. *Ibid.* *Sal Circulatum*, p. 576. *Sal Circulatus*, p. 628; *Sal Circulatus Paracelsi*. § 23. p. 700; of which he made mention in his Book *de Renovatione & Restauratione*. If, therefore, *Van Helmont* has acted candidly and honestly in this

affair, we may from these synonomous terms, and the writings of *Paracelsus*, make an attempt towards a discovery of this wonderful *Menstruum*.

Its origin.

But before we proceed to this, we must in the fourth place consider its origin. First then it is never found spontaneously in Nature; for here Nature is deficient, § 12. p. 56. where he expressly asserts, that part of Earth may be homogeneously reduced into Water by Art; but strenuously denies, at the same time, that this can ever be effected by Nature alone, because in Nature the agent is wanting by which true Earth may be reduced into Salt and Water. Nor is this produced except by the chemical art, which alone discovers a *Latex*, which cannot be transmuted, being reduced to the smallest Atoms that are possible in Nature. § 27, 28. p. 94. Nor is this to be effected by vulgar Chemistry, but by the labour of Wisdom. *Ibid.* § 23. p. 700; and that, as he expressly asserts, as its ultimate and most perfect production. And lastly, he says, Chemistry, as its most excellent effect, prepares a *universal Solvent*. § 65. p. 387. Nay, and in the whole Art there is not any operation more difficult than the preparation of the *Alcabeft*; nor is there in the whole Art any thing more laborious. Nor can the knowledge of this Operation be acquired either by reading, or meditation, but by a fulness of science, and that too doubly confirmed; and hence very few are acquainted with it. § 23. p. 700. And for this reason this *Liquor*, whose Operation is vastly tedious, cannot be obtained by human understanding; For though a person should have so much skill in the Art as to be properly qualified to come to the knowledge of it; yet unless the Most High, by a special favour, leads him to it, he will never arrive at it; for he must be chosen by a particular privilege, whoever becomes Master of it, § 27. p. 714. For God alone is the dispenser of it, for reasons which are known to the Adepts, § 2. p. 704. From this origin of it, therefore, thus delivered by *Helmont*, we may see how much they are mistaken, who idelly imagine, they shall be able to prepare it with a little trouble. These vain boasters certainly thus discover both their ignorance and their dishonesty. Nor let them impose upon you, by pretending to more things of the same nature; for *Helmont* absolutely refutes every thing of this kind, by plainly asserting, that as in the whole compass of nature there is but one Fire (*Vulcanus Ardens*) a burning Fire, so there cannot be but one Liquor, which will dissolve all Bodies into their first Matter, without any alteration in itself, or diminution of its strength; as the Adepts know and testify, § 6. p. 677, 678. Being secured, therefore, by this doctrine, I have been able to silence many illiterate persons, rich in promise and expectation, and sometimes crafty Foxes too, by only asking them one or two questions, by their answers to which I soon perceived how little they understood of what they boasted of.

Fifthly, its
Vertues.
First, with
regard to its
Object.

But let us now proceed to examine into the stupendous vertues that are ascribed to this wonderful, and almost tremendous *Arcanum*. This *Menstruum* then can efficaciously exert its dissolving power upon all sensible Bodies whatever, whether Simple or Compound, Volatile or Fixed, Solid or Liquid, Animal, Vegetable, or Fossil; nay, upon Gold and Mercury themselves, upon which nothing else can act to their intimate parts. Thus hear him speaking himself. (*Nostra Mechanica*) Our Mechanics have discovered to me, that all Bodies, whether rocky, stoney Substances, or Gems, Flints, Sand, Mercasites, Clay,

Clay, Earth, Bricks, Glafs, Lime, Sulphur, &c. may be transmuted into an actual Salt, æquiponderant to the Body from whence it is procured: And Vegetables, Flesh, Bones, Fish, and every thing like them, I have known to be reduced by it into their three mere Principles: Metals, however, on account of Anatic Commixture of their Seed, and Sand, are reduced to a Salt with a great deal of difficulty, § 11. p. 43. For Sand, or original Earth, resists both Art and Nature, nor will by any helps of Art or Nature be made to recede from its primitive constancy: But under the power of the Artificial *Infernal Fire* alone, Sand becomes Salt, and at last Water, §. 45. p. 15. Again, The *Alcabeft* of *Paracelsus*, by subtilizing them, transmutes all natural Bodies, §. 7. p. 57. And in another place, all Bodies are easily reduced to Water by the application of the *Liquor Alcabeft* of *Paracelsus*, §. 6. p. 85. Even those that otherwise refuse to be resolved into their three Elements, *Ibid.* By the help of this likewise, all Vegetables are commutable into a Liquor, which may be distilled without any *Fæces* remaining at the bottom of the Glafs, §. 27. p. 88; even oaken Coal itself, *ibid.* §. 29. For one and the same Liquor, *Alcabeft*, perfectly reduces all tangible Bodies in the Universe to their first Life, §. 11. p. 266; even all Poisons themselves, §. 49. p. 374. And which dissolves every thing besides itself, as warm Water dissolves Snow, §. 24. p. 380. §. 65. p. 387; Oil itself, and Spirit of Wine, p. 576; Cedar Wood, p. 634; All kinds of *Elixir Proprietatis*, 635; The *Ludus* likewise of *Paracelsus*, p. 700; Mercury, §. 10, 11. p. 776; Gold itself, §. 10. p. 706, which cannot by any other Solvent whatever be radically destroyed into its constituent Principles, as it is much easier to make Gold out of what was not Gold before, than to produce any thing from Gold which shall not be Gold. To this agree all the whole Tribe of Adepts, who unanimously assert the truth of it.

In the sixth place, let us consider the manner in which the *Alcabeft* exerts its power upon these its Objects. And here we find its efficacy is always excited by Fire, and this applied only in a gentle degree, whether it acts in digestion, distillation, or cohobation. For he mixed the *Alcabeft* with Coal made from Oak in equal parts, and digested them for three days in a Bath-heat, in a Glafs hermetically sealed, and the Solution was then compleated, §. 29. p. 88. The *Sal-Circulatum*, by digestion only, reduces every sort of Oil, and Spirit of Wine, into a prodigious different form, from what they were in before, p. 567. If the *Alcabeft* is mixed with an equal weight of Cedar-wood reduced to small pieces, and is exposed to a kindly warmth in a sealed Glafs, the whole Wood will, in a week's time, be reduced to a milky Liquor, p. 634. Sometimes too, the work is done by one simple distillation: For if the *Liquor Alcabeft* is distilled once only from common Mercury, it leaves it at the bottom coagulated, and pulverizable, and neither increased nor diminished in its weight, p. 628; which is effected in a quarter of an hour, p. 776. But sometimes a cohobation is necessary, in order to accomplish your design. For frequently, when Bodies are converted into a Salt of the same weight they were of before, they must be cohobated some number of times with the *Sal-Circulatus* of *Paracelsus*, before they will intirely lose their fixity, §. 11. p. 43; which happens chiefly in Metals, Gold in particular, on account of the perfectly equable commixture of its Seed, *ibid.* On the other hand, if by one distillation only it is drawn off from the *Ludus*, or *Cevilla* of *Paracelsus*, this distillation,

Sixthly,
with regard
to its method
of acting.

distillation, in so small a space as that of two hours, it converts the whole Stone into a Salt of the same weight. As for any other manner of applying this universal Solvent, I can find none, nor does it appear by any argument, that a greater degree of Fire is necessary for the operation. By a gentle agitation of its parts therefore, excited by the Fire, it is capable of dissolving all Bodies. For the *Alcabeft* itself rises in distillation with the second degree of a Sand-heat, §. 29. p. 88. But it does not ascend with a Bath-heat, §. 29. p. 88. 634.

Seventhly,
its effects.

But farther, there was nothing ever observed in all Nature, or even related, that is more surprizing than the physical effects which these Authors ascribe to the action of this *Menstruum*: For it intirely converts the whole Body of its Object, into a Matter which has neither gained nor lost the least weight during the Operation; and this transmuted Matter seems always to be liquid or saline. In this affair, however, there is some variety: For Mercury, by the action of the *Alcabeft*, is reduced to a fixed Powder, which is pulverizable, resists a Wind-Fire, and remains fixed if mixed with Lead. §. 10, 11. p. 776. Almost all other Bodies are converted into a Salt æquiponderant to their former Mass, §. 11, 15. p. 43. §. 12. p. 56. An oaken Coal is soon changed into two diaphanous Liquors, which differ in situation and colour, §. 29. p. 88. Cedar-wood is converted into a milky Liquor of equal weight with it, and then farther into a twofold Oil, which afterwards, by simple digestion, are changed into a pure Salt, so that it may be mixed with Water, p. 634. But the *Ludus*, or *Cevilla* of *Paracelsus*, which is a Stone found at the bottom of the *Scheld*, near *Antwerp*, is within the space of two hours only, converted by a gentle distillation into a Salt æquiponderant with the concrete, which being exposed to the Air, dissolves, and runs into a Liquid, without leaving any *Fæces* at all, §. 23. p. 700. From this whole account, then, it is evident, that this Solution at the beginning is performed after different manners, but that at last, however, it reduces all Bodies into a kind of Salt that may be dissolved in Water, Mercury alone excepted, which on account of its perfect simplicity, which renders it more pure than Gold, and exceeding like pure Water, refuses to be converted into a Salt; and hence it radically resists all division possible to be effected, either by Art or Nature, and for this reason is perfectly indestructible, §. 8. p. 55. §. 10. p. 705. These Bodies, however, after they are by the help of the *Alcabeft* reduced to an æquiponderating Salt, still retain their proper vertues, which depend upon the seminal property of them, and which therefore are peculiar to them, and not common to others. This very remarkable circumstance is described, §. 7. p. 55. where he says, the *Alcabeft* of *Paracelsus*, by subtilizing them, transmutes all Bodies in Nature; for Bodies, when they are reduced to their utmost possible subtility, at last pass into another substance, with a retention of their seminal Properties. And §. 65. p. 387. By the universal Solvent, all things return back to their *Ens primum*, and exhibit their native qualities, whence they have an opportunity of acquiring great and unlimited powers. But more plainly still, §. 6. p. 677, 678. while he asserts that this Liquor alone dissolves all Solids into their first Matter, without any diminution, or alteration of itself. And therefore, he cries out, get but acquainted with this homogeneous, immutable Solvent, which resolves all its Objects into their first liquid Matter, and

and then you will be able to look into the intimate essences of things, and examine their qualities, § 25. p. 780. By this means, therefore, all these Bodies are converted into a saline volatile Matter, which still retains their particular *Spiritus Reſtor.* Hence it may be intimately mixed with any Humour of the human Body, with that circulate through all its Veſſels, and in its whole paſſage every where exert thoſe powers which are proper to it, with regard to our Body. Theſe, therefore, they called Potables. Hence, then, we ſee, what the Adepts meant by potable Gold, and how vain and deceitful the boaſt of thoſe Perſons is, who pretend to be Maſters of it. Gold, when it is corroded by Acids, will ſtill give you again its actual Particles of Gold, tho' they then lie concealed in the Acid: But the philoſophical potable Gold, is a ſaline Liquor æquiponderant to the Gold, without any *Menſtruum* whatever united with it, being only the pure ſimple firſt Matter of the Gold, or its *Ens primum*. See in particular § 23. p. 700. Here, therefore, above all, it is particularly remarkable, that the *Alcabeſt*, whiſt it thus diſſolves, never mixes itſelf at all with its Solvend, but remains perfectly ſeparate from it. Hence, therefore, it neither increaſes nor dimin iſhes the ſubſtance of the Body diſſolved, but leaves it exactly the ſame as it found it. This you evidently ſee, § 28. p. 88. where he ſays, that the two Liquors of the diſſolved oaken Coal, which were different in Situation and Colour, roſe with the Warmth of the Bath, whiſt the ſolvent Liquor remained at bottom, of the ſame weight it was before. For it finds no Body with which it can be joined, itſelf being too pure and ſubtil, and reduced to its leaſt Atoms, and hence diſdaining all ferments, and always remaining ſingle, § 27, 28. p. 94. Hence it acts only by an external action, not concreting with its tranſmuted Object, as the pureſt Fire uſes to act upon its Object, as warm Water melts Snow, § 24. p. 380. § 6. p. 677, 678. For this Liquor leaves nothing of itſelf mixed with its Solvend, § 10, 11. p. 776. Hence, therefore, beſides others, this *Menſtruum* ſeems to have two excellent advantages above all others: In the firſt place, that it does not act by attraction, or repulſion, but only by a mechanical diſſolving Power, contrary to all others that we are acquainted with, Fire, perhaps, alone excepted: And then, ſecondly, that it always preſerves intire the native Powers of its Solvends, and yet whiſt it reſolves Poiſons, it deprives them of their violent and deadly quality, and gives them the moſt excellent medicinal virtues, by reducing them to their *Ens primum*, § 49. p. 374. which, however, it muſt be allowed, is very difficult to comprehend. When Bodies, now, are by the help of the *Alcabeſt* reduced into their ſaline volatile *Ens primum*, retaining at the ſame time all their ſeminal qualities, if they are then urged any farther by the action of this Solvent, they are perfectly deprived of their proper ſeminal virtue, and from every one, how different ſoever, there is produced the ſame unactive, inodorous, inſipid, ſimple, elementary Water; ſo that by too great an application of the very ſame *Menſtruum*, whatever excellence was produced before, is now deſtroy'd. It appears, therefore, that the ultimate matter of all tangible Subſtances is Water, upon which the *Alcabeſt* itſelf can act no farther, but which being again impregnated with the ſeminal ſæcundity of any Seed, may be converted again into any new Bodies whatever. Hear what he ſays himſelf! Every Body is tranſmuted into an actual

actual Salt æquiponderant to the Body from whence it is made; and this Salt being cohobated some number of times with the *Sal-Circulatum* of *Paracelsus*, loses intirely all its fixity, and is transmuted into a Liquor, which itself likewise at last becomes an insipid Water, of the same weight with the Salt from which it proceeded, § 11. p. 43. Original Sand, by the artificial *Infernal Fire* alone, is changed into a Salt, and then a Water, § 15. p. 45. And I know a *Water* by the mediation of which, all Vegetables are converted into a distillable Juice, which rises without leaving any *feces* at the bottom of the Glass; and which Juice being distilled with Alkali's, is totally reduced into an insipid elementary Water, § 27. p. 88. An oaken Coal turned into two Liquors by the *Alcabeft*, and then mixed with a little Chalk and distilled, rises with almost its former weight, and has all the qualities of Rain Water, § 29. p. 88. And then they all become so volatile, that they rise with a Bath-heat, and fly off from the *Alcabeft* which remains at the bottom, § 29. p. 88. § 24. p. 380. p. 634.

Eighthly, its
proper im-
mutability.

But what is much more surprizing than all the rest, is in the eighth place, that this *Menstruum*, whilst it operates so wonderfully upon all other Bodies, is not in the least lessened, altered, or weakened in its efficacy by any of them: So that in this respect again it resembles Fire, and is with a great deal of reason compared to it. By a very expressive Phrase, therefore, it is said to act, by its power of acting upon all sublunary Bodies, without reaction, § 15. p. 45. And that after it had dissolved the oaken Coal in so extraordinary a manner, the solvent Liquor remained at the bottom of its former weight and strength, § 29. p. 88. For its transmutation is despaired of, as it cannot find any Body worthy enough to be wedded to, and is single with regard to every commiscible ferment, to which it might be in subjection: And hence it cannot die, § 27, 28. p. 54. In its most perfect action, therefore, it reduces every tangible Substance to its middle life, without any change in itself, or diminution of its strength, § 11. p. 265. It is immutable, therefore, and immortal, § 3. p. 377. This alone, by operating, is not altered, § 24. p. 380. § 6. p. 628. 634. 677, 678. It acts, therefore, without any re-action of the Patient, or depauperation of the Agent, § 27. p. 704. § 10, 11. p. 776. For this Dissolvent is homogeneous and immutable, § 25. p. 78. and being the same both in number, weight and activity, it is as efficacious, the thousandth Operation, as it was at first.

Ninthly, its
Volatility.

But among other things remarkable in this *Menstruum*, is, in the ninth place, its degree of Fixity or Volatility in the Fire: And this again is exceedingly surprizing. For after it has rendered all Bodies, the most fixed not excepted, so volatile that they will rise with the gentle heat of a Bath, yet itself remains fixed at the bottom, nor ascends with them, § 14. p. 56. § 27. 29. p. 88. § 10. p. 634. 700. 776. In the mean time, however, the *Alcabeft* itself is so volatile, that it rises in distillation together with the Bodies it has dissolved in the second degree of a Sand-heat, § 29. p. 88. And hence it may, by distillation, be drawn off from common Mercury, which it fixes, and coagulates, p. 776. 628. Hence, therefore, the compass within which the whole power of this *Alcabeft* exerts itself, is accurately determined.

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In the tenth and last place, before we quit this subject, we must observe to you, that this *Solvent*, that thus remains intire in all its Operations, nor is ever overcome, or fatigued by the resistance it meets with from any thing, does yet acknowledge one Body in Nature with which it may be so united, as to be brought into Wedlock with it. This appears evident, by considering the Text of the Author. § 27, 28. p. 94. Chemistry was solicitous about finding out a Body, which should have so great a sympathy of purity, that it should not be dissipated by any corruptent. And at last Religion was astonished to see a *Latex* discovered, which being reduced to the least possible Atoms in Nature, remained single, and disdained to be wedded to any Ferment. Its transmutation therefore was despaired of, as it could not find any worthier Body with which it might be united. But the labour of Wisdom found out an anomalous Body in Nature, which rose without any commiscible ferment different from itself. This Serpent bit itself, revived from its Poison, and afterwards knew no Death. So that we see here the conjunction of two things which were in some measure different. But he intimates this still more plainly and distinctly, § 11. p. 265. where he says, that one and the same Liquor, *Alcabeft*, reduces all the tangible Bodies in the Universe to their first Life, without any alteration in itself, or diminution of its strength, but is brought under the yoke, and altered by its equal alone. And in another place he comes still nearer the matter, § 14, 17. p. 56, 57. telling us, that when Mercury is perfectly freed from the original Sulphur, which intimately adheres to it, it is not afterwards mutable by any Fire, but immediately destroys all other Seeds, except its equal.

Tenthly, its submission to one certain thing.

Thus, Gentlemen, I have faithfully laid this affair before you. Concerning any thing of this nature, I have not, to my knowledge, read a Word any where but in these Authors. Neither the ancient Philosophers, nor any other Chemists or Physicians ever mentioned, or heard of any such thing; and yet, of every thing we want in Physics, it is vastly the most to be wished for. You will, no doubt, therefore, be mighty solicitous to know in what kind of Matter it ought to be sought; for which reason I will add a few words upon this head, having tried a vast variety of things myself, which I have sometimes repented of with indignation. *Paracelsus* then had a Liquor which he prepared by an infinitely tedious circulation from Sea Salt, in which Nature has placed the greatest perfection. This by an indefatigable application he still advanced to a perpetual Oil; and then he called it the *Ens Primum salium*; *Oleum Salis*; *Liquor Salis*; *Aqua Salis*; *Circulatus Sal-minor*; *Circulatum minus*; L. IX. *Archid.* under the remedy *ad Maculas*. In his Treatise *de Sale*, C. IV. *in correctione & additione*. Lib. *de Renovatione* Arch. IV. Cap. 4. *Essentia de Salibus*, Archid. L. VIII. Cap. *de Elixire Salis Quintæ Essentiæ extractio de salibus*, Archid. X. Cap. 2. And the preparation of this *Sal Circulatus*, which is vastly troublesome, is there described. nor is there any thing obscure in it, except that we don't know what the Spirit of Wine is, that is there required to separate the impure from the pure. This now agrees exactly with the Opinion of *Van Helmont*; for he says, that the Salt of Bodies being some number of times cohobated with the *Sal Circulatus* of *Paracelsus*, is converted into Water, § 11. p. 43. And hence to the *Primum Ens Salium* he ascribes the virtues of the *Alcabeft* itself, p. 419. And

Of the Matter of the *Alcabeft*. Sea Salt for the *Circulatum minus*.

says, that by the *Sal Circulatus* all poisons die, § 9. p. 374. And hence he calls it the most happy, perfect Salt, which is reduced to the ultimate degree both of purity and subtilty, and hence pervades every thing, that alone remaining immutable during its operation, by which it readily dissolves every thing else, § 24. p. 380. This *Sal Circulatum* acts wonderfully upon Oil, and Spirit of Wine, p. 576. This *Sal Circulatus* reduces Bodies into the Liquor of their concrete, p. 628. And with that may be prepared the *Ludus*, § 23. p. 700.

And Mercury to be united with the *Circulatum minus*.

But *Paracelsus* had another Solvent, much more powerful than the former *Circulatum minus*, and much more difficult to be come at, which, therefore, he called his *Circulatum majus*, *Archidox.* x. C. 4. And hence in the same place he calls it, likewise, the *Materies Mercurii Salis*; and afterwards, *Living Fire*, *Archid.* x. C. 5, 6. In common Mercury he supposes there is a most perfect Fire, and a latent, celestial life, and that the quintessence of Mercury is celestial Fire, if it is dissolved with its Mother, viz. an *Arcanum* of Salt, *Archidox.* x. C. 6. When these two, therefore, by a true adunation, are intimately united together, and together rendered pure, subtil, and volatile, then seems to arise that wonderful mercurial Water, which he describes in the Chapter *de Corrodente specifico*, where he says, that Gold so dies there, that it continues to be Gold no longer; whereas in all other corrosions of Gold, the Gold is only divided into very small Particles, but still remains the same true Gold, and by an artificial reduction may be always recovered again. By this art, therefore, there is a perfect union of Water with Water: For there is a two-fold Water, viz. a common one, which is in Salt, and a metalline one, which is in Mercury, both which, however, have the same Root. All this now seems to have been understood by *Van Helmont* exactly in the same manner, and therefore in a few words I shall just add what he has said upon it. Please therefore to hear him speaking, § 8. p. 55. The internal Mercury of Metals, perfectly freed from every taint of a metalline Sulphur coheres together with an indissoluble union, so that it radically resists all possible division either by Nature or Art. Nor could I learn the nature of Water, except under the Rod prepared from Mercury's Wand. And I found the nature of Mercury adequate to Water: For it does not contain the least Earth in it, but is always the Son of Water alone, § 10. p. 56. 705. And he says with all the ancient Alchemists, if I had not seen that Mercury eludes all the labour of the Artists so, that it either flies all off from the Fire still intire, or else all remains in it, and both ways retains its immutable identity, and the anatic homogeneity of its identity, I should say that that art was not true, which is true without any falsity, and by far the truest of all. So that what is above is like that which is beneath; and the contrary. And hence it is absolutely impossible either for Art or Nature to find any different parts in the homogeneity of Mercury, not even by the *Alcabeft* itself, as Mercury is more simple than even Gold itself, and formed with a greater anatic identity. And hence, therefore, there is in Mercury the *Ratio proxima* of indestructibility, as in the Elements themselves. Hence all sublunary things are too weak to subdue pure Mercury, or to penetrate, alter, or defile it. It remains secure in Air, Fire, and the acrid Liquor. It is not affected by any Solvent, much less penetrated through by Air. And, there-

fore, there is nothing in Nature like this pure Mercury, no not at a distance, § 17. p. 670. It resembles, therefore, the *Ens Metallicum*, and comes very near it, § 4. p. 705. And at length, actually existing simple, and not as a constitutive part of things, § 17. p. 670. From these principles, then, we know, that it is brought under the yoke, and changed by its equal alone, § 11. p. 265. For this anomalous Body in Nature, rose without any commiscible ferment different from itself; but it bit itself, revived from the Poison, and afterwards knows no death. Thus, then, Gentlemen, you have the History of the *Alcabeft* of *Paracelsus*, and *Van Helmont*, which I have extracted from their own Writings, and laid before you with the utmost fidelity. Here, therefore, you see at once, that it is in vain to seek for this *Menstruum* in human Urine, or any of its productions. Nor can it ever be found in Tartar, or any of its Preparations, tho' this may be substituted as Regent to the Prince, § 25, 26. p. 780. Nor can Phosphorus ever be reduced to it: The properties that have been proposed won't admit of it. *Glauber* too is mistaken, when he seeks it in the fixed Alkali of Nitre: As *Zwelfer* is in hoping to find it in the most acid Spirit of Vinegar distilled from Verdegrease. Nor does the famous *Guernerus Rolfincius* seem to have had a right notion of it, when he supposed it to be threefold from a fixed Alkali as the *Basis*, viz. in Fossils from an Alkali of Tartar, and Vinegar of Antimony; for it is a mere vitriolated Tartar that is thus produced: In Vegetables from an Alkali of Tartar saturated with Vinegar; for this gives a mere tartarized Tartar: In Animals from the same Alkali saturated with the acid Whey of Milk; for hence arises a tartarized Tartar, but a more valuable one: Nor does the addition of *Sal. Ammoniac* much alter the case, *Eph. Germ. D. I. Ann. 6, 7. p. 193—196. App.* And indeed, no-body in the description of the *Alcabeft* has come nearer to the Sentiments of *Paracelsus* and *Van Helmont*, than *Peter John Faber*, in his Manuscript concerning Alchemy, to the most serene Duke of *Holsace*, which is printed in *Eph. Germ. D. II. Ann. 8. App. p. 111. 117.* out of which these remarkable words confirm my opinion. The Liquor *Alcabeft* is a pure mercurial metalline Spirit, so converted to its proper natural Body, that these two become one inseparable indestructible being, destroying every thing else, and converting them into their first Matter. It is the true *Mercurius Philosophorum*, prepared from the Mineral Kingdom, joined to its own Body, inseparable from it, being a milky, buttery Liquor, penetrating and dissolving every thing. This, now, is of two kinds, Simple and Compound: The Simple is made from a pure metalline Acid, and a pure metalline Salt, rendered volatile with its Spirit; and the Preparation of this is exceeding difficult: That, however, of the Compound, is still far more so; for this is prepared from a mineral Acid, and a pure animal and vegetable Salt. The Liquor *Alcabeft*, or the perfect pure *Mercurius Philosophorum*, is like Fire of an incorruptible unalterable nature, reducing every thing to its first Matter. And the very sagacious *Joachim Becherus*, in his *Subterranea*, is almost of the same Opinion: For he asserts, that he has discovered in Sea-Salt, a certain arsenical and mercurificating Power, which was it but separated and pure, would be the *Alcabeft* itself, which, however, would be perfectly distinct from the *Mercurius Philosophorum*. Hence Mercury itself, he looks upon as a sulphuro-metalline Substance, which of itself would be solid, and receive all its Fluidity from an arsenical Sulphur of com-

mon Salt. This very subtil conjecture, I wish he had more clearly demonstrated. The sum of this Gentleman's Argument is this: The purest Silver, corroded by Spirit of Nitre, and precipitated by Spirit of Sea-Salt, becomes volatile, and then easily disposed to part with its Mercury; and therefore Sea-Salt can transmute the purest Metals from their fixed Nature into true Mercury. Perhaps, now, at last you may be willing to know my Opinion of this matter, and whether I believe that any of the Chemists were ever Masters of this grand *Arcanum*. To this I freely answer: *Van Helmont* complains, that the Bottle was once given him, but that it was taken away again, and therefore he could not make many Experiments with that Liquor: And *Paracelsus* does not say so many, and so great things of his Solvent, and therefore, I really don't know what to say of it. This, however, I'll venture to say, and would advise you to try it, that if you will but examine Sea-salt, and Mercury, in every chemical Method you are acquainted with, you will never repent of your Labour.

Of Chemical Vessels, and the Furniture of an Elaboratory.

As the business of Chemistry is concerned in producing and observing the changes of Bodies, and as these changes are particularly effected by the application of Fire, hence the Operators necessarily stand in need of Instruments and Vessels, without which it is impossible for them to exercise their Art. By a Vessel, now, I mean every hollow Body, in which the Matter to be chemically changed, or actually changed, is contained, as likewise the changing Body or Solvent. An Instrument, I shall call every body that has that strength, size and figure, as to make it fit to apply the changing causes to the Bodies to be changed in such a manner, as by means thereof, to excite such a motion as the rules of Art determine, and by the assistance of which, the Operator shall be able to manage both those causes, and those Objects. In general, then, your chemical Furniture must consist of Bodies to be changed by Art, of causes capable of effecting such changes, of Vessels, Instruments, and Bodies actually prepared by the chemical Art, if you would have your Elaboratory compleat.

Chemical
Vessels.

Chemical Vessels, to which the Objects to be changed are committed, must be able to contain such Bodies, and their solvent causes, and at the same time to bear the Fire that acts upon, that they may not prove defective in the middle of their Operation. It is necessary, therefore, that these should be very strong, and of such a nature, as not to taint their Contents: And these one may call containing Vessels. And those on the other hand, that receive the Substances after they are changed by their causes, which are almost always separated by the force of Fire from the Body, which in the containing Vessel either does then bear, or has born that force, we may call Receivers: And in these Vessels we have particularly to consider, the Matter, and the Figure.

The Matter
of the Vessels.

The Matter of the Vessels, is either Wood; Clay; Stone; Metal, or Glass.

Wooden Vessels, made of dry Wood, not oily, or painted, are reckoned best for keeping Salts, saline Bodies, Limes, and calcined Substances, if they are put in them, when they are both very dry, and the Vessels are then stopped very close: For in this manner those Bodies use to keep, which in almost all others

others melt from the Moisture of the Air. Mortars and Bowls too, turned out of Wood, are used to advantage, particularly for rubbing Metals with Water that are dissolved in Mercury, for which purpose they are better than any thing else. These too are of service in reducing melted Lead and Tin to Powder, if they are first rubbed over with Chalk: And these are the chief Uses they are put to.

Vessels made of Glass are of excellent service, because they neither change, add, or take away from the Bodies they contain; and whilst they are exposed to the action of the Fire, they suffer nothing to transude through them from within, nor admit any thing from without, except Fire, and Magnetism, containing and bearing even the *Alcabeft* itself in the Fire. In every Experiment, therefore, we want to make, and in every chemical Operation, these, and these only ought to be made use of, when there is not required a greater degree of Fire than Glass is able to bear without melting. And as the *German* green Glass which least of all affects the contained Bodies, is the most incorruptible, and bears the Fire a long time without being fused; hence that is preferable to every other sort for these purposes. As for the white, which is almost like Chrystal, and easily flaws, and sweats out its Alkali, that must be rejected here, because it melts too easily, and communicates its Alkali to Bodies, as appears too evidently. The green Glass, I mention, will bear more than 600 degrees of Heat before it is put in fusion, but how much more exactly, I don't yet know: In the greatest Sand-heat, however, I have brought it to melt. It is evident, therefore, that this can bear a considerable compass of Fire, without any inconvenience, tho' beyond certain limits, it can sustain it no longer. It were much to be wished, therefore, that *Van Helmont* had acquainted us with that secret Lute, with which a glass Vessel being coated, it would bear the strongest open Fire of a Wind-furnace, without melting, so that he cou'd with Glass distill the igneous Oil of Vitriol. This Crust is said neither to split, crack, fall off, nor vitrify. And thus in the greatest intensity of the Fire, this Coat is said to incrustate the Glass internally, *Helm.* § 19. p. 707. If this was true, then all Operations might be performed in Glass; but, I confess, I know of no such coating, nor have ever met with any body that did.

The third sort of Matter made use of for chemical Vessels is Metal. Of Metals, now, Iron melts with the most difficulty; and hence a great many Vessels are made of Iron. All metalline Vessels, however, have two inconveniencies, the first that they are corroded by Salts when they come to be red hot, and hence both spoil their contents, and are themselves destroy'd: The second, that they melt in the Fire. This I myself have had experience of; for I got some iron Long-necks made of cast Iron, in order to distill Phosphorus from Urine, but they melted long before the Operation was finished.

In the fourth place, therefore, the Chemists make use of Vessels likewise, made of Potters Clay. But these too, when they are made of a fat clayey Earth, vitrify when they come to be exposed to the greatest degree of Fire, and thus prove deficient. The best, therefore, are those made of a poorer Earth, such as the *Hessian*, and the like, which are made of crucible Earth; for these bear the most intense Fire. But these, too, as they are porous, transmit some saline Particles, especially when you make use of them in the distillation of acid Spirits. Of this variety of Vessels, now, it is evident what sort are the most

proper

proper for any particular Operations: Pure aqueous Liquors, for instance, and perfect fermentative Spirits, may be distilled in Metal: Acetose, distilled, fermented vegetable Spirits conveniently enough too in Tin: Other saline Substances require Glass. The spiral Tubes made use of in the distillation of acetose Liquors, are made of Tin; but it's best always to make the Head of Glass, for the reasons just mentioned. Earthen Vessels are never made use of, but where there is required a very great degree of Fire, and then, that they may transpire less, and be not so apt to crack, they should be always coated with a proper Lute. When you are perfect Masters then of this affair, before you begin any chemical Operation, you must consider the nature of the Matter to be operated upon, and the degree of Heat it will require, and hence you will easily see what kind of Vessels are fit for your purpose. And here, where one is perfectly at one's liberty, one wou'd always prefer Glass, if it was for no other reason, than that one can here look into the Vessel, and observe all the *Phænomena* that happen to the Bodies within, during the Operation; which setting aside the gratifying one's curiosity, is of excellent service both in Chemistry and Philosophy, as by this means we come at the origin of a great many appearances. The *Indian Potters Earth*, of an ash colour, is like *China*, and is, perhaps, a *Species* of it. The Potters make Vessels of this Earth of all sizes, in which they put up their Pickles and Sweet-meats, to send abroad. These are neither corroded nor penetrated by Acids: And hence your Distillers of *Aqua Fortis* make use of them, to keep their acid Spirits in.

The best Figures of Vessels for keeping Bodies.

Vessels, now, let them be made of what Matter you will, may differ vastly in their Figure; of which, with regard to chemical uses, I shall just add a few words. Those glass Vessels that are designed for putting volatile Liquors, and Salts in, are best, I think, made with a plain bottom, hollowed inwards, the sides rising cylindrically, and terminating at top in a narrow cylindrical Neck. The mouth of these must be secured with a glass Stopple, ground nicely to the concavity of the Neck: And the larger that part of the concave Surface is, that the Stopple is in contact with, the more nicely it will answer the end. But those Vessels out of which Liquors are to be dropped, should be made with a spherical Belly, and the Neck of these too should be cylindrical, and the Mouth of them produced into a Rim, which on the upper part should be a little hollow. These may be stopped with a Cork, or if you keep volatile acid Spirits in them, with the Gardiners yellow Wax. The Figures of these you see in Plate IX.

For chemical Operations.

Other Vessels which the Artist wants for the separation of Bodies by Fire, which is generally done by distillation, require different Figures according to the different ends to be answered. And here it is necessary that these should be of two Sorts, one for containing the Body to be changed, and bearing the Fire necessary for the Operation; the other for receiving what is separated out of the other by the action of Fire; which are almost always colder. I shall now then consider the Figure of each of these.

Crucibles and other melting Vessels.

If the Body to be changed and separated in the Fire, is to have nothing but its fixed part preserved, then the Figure of the Vessel made use of, is almost always an obtuse Conoid with its *Base* at the top, and truncated *Vertex* at the bottom: And these are varied through all the degrees, from this conical Figure, to a concave spherical Segment. Thus the melting Pots called Crucibles are

are conical, but the smelting Vessels used for ustulation, and calcination are concave parts of a spherical Segment. In these Vessels, the effect of their Figure is this, the shallower the Vessels are, and the more they diverge from the bottom, the more easily will the volatile Matter fly off from the fixed, and the Fire will be applied to a larger Surface both of the Matter to be separated, and that which remains fixed; and hence for ustulation, the lowest, and openest Vessels are always made use of.

But when the volatile Matter, separated from the fixed, is to be saved as well as the fixed, then the containing Vessel has a three-fold Figure, *viz.* Distilling
Vessels. either a cylindrical one, a conical one, converging upwards, or a conical one, Pl. X. converging downwards. The cylindrical, by its sides only keeps in the volatile Bodies, but neither forwards or impedes their ascent: The whole difference, therefore, in this sort, arises from the height; and hence, as is the height, so is the diversity of the operation. In order to separate the most volatile Bodies from the less volatile ones, these cylindrical Vessels must be very high; and the contrary, when you want to separate Bodies that are almost fixed, from those which are perfectly so. But when from a narrow bottom, the Vessels are expanded upwards, as in the Hemispherical Cupels, or those that are only the segment of a Sphere, then it is plain from Hydrostatics, that every point of the concave base will sustain an incumbent column of Liquor, whose height is measured by a line drawn perpendicular to the horizon from that point to the surface of it. Hence, therefore, it is plain, that the columns will be always so much shorter, the nearer you come to the edge; for which reason this diverging figure wonderfully forwards elevation; and on this account exhalation is effected by it most expeditiously. Thus then we have an idea of the Vessel called a Retort; for it is a hollow Sphere terminating in a cylindrical neck, whose upper horizontal line is a tangent to the upper point of the Sphere, whilst the inferior one produced, forms a diameter to the Sphere parallel to that tangent. Such a Vessel, therefore, easily determines the separated Matter into the cylindrical Aperture, and thence, into the Receiver, which is here very easily raised by the Fire, and confined and repelled by the arched figure of the Vessel. This Vessel, therefore, is fittest for separating by distillation those parts which are very fixed from those which are absolutely so; as in the distillation of Oil of Vitriol, Spirit of Nitre, *Aqua Fortis*, Spirit of Salt, Spirit of Alum, and the like. But the Workmen generally bend the neck downwards, and draw it out into an open conical end, that the Vapours which are propelled into the first part of the neck, may afterwards spontaneously run down, and distill; and with this view are made all your common Retorts. But for very tedious distillations, where a long continued application of the Fire is requisite to raise and expel Particles that very strongly resist such an elevation, I got some cylindrical Vessels made, which when they were placed in a horizontal position, in their upper horizontal part opened into a horizontal neck, as you see Plate X. with these are most conveniently distilled Phosphorus, and all Liquors that rise with a great deal of difficulty; and if you will try them, you'll be pleased to find some very difficult Operations rendered much more easy. When I distilled however yearly before you such large quantities of Oil of Vitriol, and fossil acid Spirits, in my private Lectures, you remember I always instead of Retorts made use of cylindrical, earthen Long-necks, which open with a large, circular

lar mouth. These, when they are placed horizontally in the Furnace, are the best kind of Vessels, for these distillations; for cylindrical Segments being at one end inserted into the Orifices of these Pots, and at the other, into large glass Receivers, placed horizontally, likewise, and then well luted, furnish us with the safest method of distilling these acid Spirits. These all you may examine in the figures annexed Pl. X. which will readily bring to your mind what you have so many times seen, and help you to conceive properly of those you never saw before. Thus then I think we sufficiently understand the fundamentals of the Doctrine of the figure of containing Vessels in the distillation of Bodies that rise with difficulty. And if we consider what follows from this Doctrine, we shall find this observation generally true, that with the more difficulty any thing rises in distillation, the more necessary will be the figure and disposition of these last Glasses: But on the other hand, when the Matter to be sublimed is very mobile, and in its degree of volatility differs but little from the Body from which it is to be separated, then Vessels of a contrary figure best answer the purpose. Those in the first place then are conical, which because they somewhat resemble *Hercules's Club*, are by the *Germans* and *Dutch* called (*Kolven*) Clubs, as on account of their likeness to a (*Cucurbita*) Gourd, they have obtained the name of Cucurbits; but the ancientest Alchemists, as *Lully* and others most frequently called these Vessels Urinals. And here it is very easy to conceive, that when the Liquors in these Vessels are raised by the Fire, they must run against the converging sides of the Vessel, and being there stopp'd in their ascent, will be repelled and turned back again. If there is any thing therefore that is raised with difficulty by the degree of Fire made use of, that rarely ascends so easily in these Glasses, but is rather repelled back again, and remains at the bottom. In these Glasses, too, this is to be observed, that the greater the latitude of the bottom where it is widest, is in proportion to the aperture of the upper orifice, through which the sublimed Liquor must pass, there the impediment and repulsion of the elevated Matter will be greater, too, so that by this means the perfectly volatile part alone may be nearly separated from that which is not so much so. And lastly, the height of these Glasses must be taken into consideration, likewise, for the greater their altitude is, the more difficult will be the sublimation of those Bodies that are less volatile. A proper regard to these three circumstances has given rise to a very beautiful invention, by the assistance of which you may with a little Fire, Trouble, and Charge, distil a large quantity of simple Alcohol, or the same impregnated with the most subtil, vegetable Spirits; and it is done in the following manner. Make a conical, tin Vessel, the Base, of what size you have a mind, 6 inches, for instance, in diameter; and let the diameter of the upper orifice be one inch, and the height be 4 feet. At the top let it be bent downwards in a cylindrical form, and at the bottom let this Cylinder be turned up again, that it may be inserted into the Mouth of a cylindrical, spiral Tube, commonly called a Worm. Then if you put some Spirit of Wine in a Cucurbit, that stands in boiling Water, and fit on such a conical Vessel to it for a head, and then distill through the spiral Tube and the Refrigeratory, you will the first time have a very strong Spirit, which upon a second repetition of the operation will come off pure Alcohol. From the same Principles we understand the nature of the (*Phiala Chemica*) Chemical Vial, as it is called, which is a spherical

spherical Body, from whose *Vertex* there arises a long cylindrical Neck, open at top: These are generally called Matrasses, or Boltheads. These, now, are of incredible use in Chemistry, in some of the nicest Operations; for as the Neck may be made of what length you please, as may likewise the proportion of the capacity of the Neck to that of the Belly, hence it is very evident, that you may give the Liquor contained in the Belly so great a degree of resistance, with regard to its ascent, that if you digest it with a gentle Fire, there shall scarcely any thing come out of the orifice at top. But in this kind of Vessels I have observed particularly, that the column of the Atmosphere that rests upon the aperture of the Neck, surprizingly compresses the Liquors that are contained in the Belly, and are agitated by the Fire, and serves as a kind of Stopple, to close up the aperture of the Neck, being at the same time kept in *æquilibrio* with the *impetus* of the Liquors that endeavour to rise; for whilst the Air being rarified by the Fire endeavours to elevate the whole superincumbent column of the Atmosphere, it meets at the same time with just the same resistance from the renitent weight: Hence then the liquid particles that are contained in this rarified Air, are repelled to the bottom of the Vessel, by which means it comes to pass, that when they are agitated by the Fire, they are strongly applied to those Bodies that lie at the bottom of the Glafs. This you see evidently with the naked Eye; for if you put some Alcohol of Wine into one of these Boltheads, that has a very long, small Neck, and hold it cautiously over the Fire, when it begins to be so hot as to be ready to boil, you will perceive Vapours ascending into the cavity of the Neck, and falling down again, like little, floating Clouds. Hence, therefore, with these Glasses, the digestion of *Menstruums* with their proper Solvents, is most happily effected, without loss either of the *Menstruum*, or the Body to be dissolved; which has been of excellent service to me in performing a great many experiments, which otherwise I could not have made. These tall Matrasses, farther, are particularly serviceable in separating the very volatile, pure, alkaline Spirits, and Salts, from their volatile Water, Oil, and Earth, from which it is so very difficult to separate them by other methods. These Vessels, however, have this one inconvenience, that when the Liquor at the bottom comes to boil, as it cannot rise up high enough, it leaves the top part of the glafs Neck cold, and hence, if the boiling Vapour ascends at once, by the sudden heat it is apt to make the Glafs fly in that place, especially if it is in the Winter, and freezes. And then, again, the Drops that are collected upon the cold part of the Neck, and hence are cold themselves, often run down among those parts that are vastly hot in the Belly or Neck of the Glafs, and burst the Vessel to pieces. This I once experienced myself, to my cost, whilst I was digesting some Mercury with this *Apparatus*. From what has been said, then, we conceive sufficiently of the efficacy of the figure of Vessels, and the necessity there is of such and such particular Forms, to answer different ends proposed. The figure of Receivers, particularly if they are large ones, is two-fold; either they are made with a spheroidal Belly; or else in form of a Cucurbit. Supposing, however, the capacity of both to be the same, then that, like a Cucurbit, is preferable to the spherical, because it being longer, the bottom is farther from the mouth of the exhaling Vessel, and hence gives the Liquors coming very hot from the Fire, a more convenient space to grow cool in: This observation I have found of

T t t

service.

service. It's very often necessary, however, to increase the distance betwixt the containing Vessel, and the Receiver; and this I told you before might be done by putting a cylindrical Tube between them, and then luting it to the Mouth of them both. But in the more nice distillations, of Mercury in particular from Metals, we are forced to make use of another contrivance to increase the distance to a proper length; which is done by the help of the Glasses you see here, which being made to fit into one another, form one continued Vessel of what length you please; their junctures at the same time being secured with a proper Lute. A Retort, Receiver, and these prolonging Vessels, which I have given you a Figure of Pl. XI. would be sufficient for all distillations, if we did not often want to separate Bodies that are very volatile from other volatile ones: But as this is daily the case, here again we are obliged to make use of tall, upright Vessels, which must have a Head fitted on to them, called by *Dioscorides* an $\alpha\mu\beta\iota\zeta$, where he writes of the sublimation of Mercury, whence by an *Arabian* variation 'twas call'd an *Alembic*, or *Alembic*, under the *Rostrum* of which you place the Receiver. You will easily perceive, now, where it is proper to make use of a Cucurbit with a Head, and Receiver, and where a Retort and Receiver. This, the easiness with which any Bodies rise, and the consideration of their being mix'd with others that are very volatile, from which they are to be separated, will sufficiently point out. You perceive too at the same time, that the principal inconvenience of this last *Apparatus* is this, that as the Alembic must be luted to the Cucurbit, and its *Rostrum* to the Receiver, you must by this means have two Junctures, which, take all care you can, will transmit some of the subtil Vapours through the cracks of the Lute. But there is often necessary, likewise, a continual reaffusion of the volatile part, upon the fixed *Residuum* from which it was separated. This the Artists generally call Cohobation, *Paracelsus*, formerly, Circulation; and this operation has the most beautiful effects of any in the Chemical Art. As the Operators, therefore, saw the great necessity of it, and at the same time found, that every time they opened their Vessels, they lost some of their Liquors, by thus pouring them back, exposed to the Air, they on this account contrived a Glass Vessel, consisting of a Cucurbit and an Alembic, the two *Rostrums* of which being turned back into the Cucurbit, perpetually return into its Belly the Liquors that are collected in the Alembic; and thus, the Vessel being perfectly secured above, the loss of the Liquor is prevented, and the trouble very considerably lessen'd: This they called a Pelican, which is so much the better, as the Tubes brought from the vertex of the Alembic are longer. But as these Vessels are not very easy to be procured, the same effect may be obtained in a simpler manner, and that is, by putting the Matter you are going to work upon into a Bolthead, with a pretty long Neck, and then fitting the Neck of a less into the Mouth of it, and securing the Juncture with a proper Lute. You must observe, however, to heat the Glasses first to such a degree as will be necessary for the Operation; for then the Air, being heated, will be proportionably expell'd out of the Vessels, after which you may lute it, make your Fire, and proceed without any danger. In this *Apparatus*, however, it sometimes happens, that the Liquor which is collected at top, and grown cool, falls down upon the hot bottom, and makes it fly: Being thus cautioned, therefore, you will take care to guard against this inconvenience.

And

And thus we have sufficiently considered Vessels for any Chemical Operations.

Of LUTES.

By a Lute, the Chemists mean a ductile, tenacious Mass, growing hard when it's dry, which serves to secure the junctures of their Vessels, that no Air may pass in and out, but particularly, that the Corpuscles, when they are carried up by Fire in the distillation, may be kept in, nor suffered to escape out of the Vessels. It is evident, therefore, that the Lutes must be different, according to the nature of the Bodies to be distilled.

Use of a Lute.

If then it is an aqueous Body you are operating upon, you need only take the flower of Linseed, from which the Oil has been express'd, and with a little White of an Egg, work it well into a Paste, and it will be sufficient; for if you put this in betwixt the Cucurbit and the Alembic, and lute with it the juncture of the *Rostrum* of the Alembic, or the Retort, with the Receiver, it will grow hard with Heat, and if it cracks, may be mended by an addition of more of the same. And in the distillation of all fermented inflammable Spirits, and volatile, alkaline, and alcoholifated Salts, the same Flower will serve if it is well work'd with clean cold Water.

The Lute for aqueous and spirituous Liquors.

But in the distillation of Acids, either acetose, or other, this Lute won't do, because in this case it will be corroded, dissolved, and soften'd, and thus will suffer the Spirits to escape. For this purpose then, you may take an Ox's or Hog's Bladder that has been macerated in Water, 'till it begins to grow glutinous, and, as it were, semi-putrid, and fasten it round the juncture, and it will answer the end excellently well.

For acetose Liquids.

But again, when with a very strong Fire you distill the corrosive acid Spirits of Vitriol, or fossil Salts, you must then have a Lute, which after it is applied, will harden like a Stone; and hence this has been called the *Lutum Sapientie*. You make it best in the following manner. Take the Colcothar that remains after the distillation of Oil of Vitriol, and boil it in Water, which renew till the last does not appear to be at all salt; and then let it be dried, and kept carefully in a close Vessel. When you want your Lute, take some of this sweet, dry Colcothar, and rub it well with an equal quantity of the best Quick-Lime, and then with a little beaten White of an Egg, work it presently into a Paste, and apply it immediately to the juncture of the Vessels, which must be dry, and something warm. This Paste then will very soon dry, and harden like a Stone, and like Glass is capable of confining any Salts. Without all this trouble, however, I prepare a Lute of the same nature, in the following manner. With a quantity of Potter's Clay, I mix so much of the purest Sand, that the Mass, if it is work'd with Water, won't stick to the Fingers any longer; and to this I then add a fourth part of common Mason's Lime, so as to reduce it to a pretty stiff Paste. And the drier this is when it is made use of, the better, if it does but remain ductile: When this then is applied to the junctures of the Vessels, it grows hard, and excellently answers the purpose. If in a very intense Fire it should happen to split in the distillation, the crack may be soon made good again with some of the same. It has this convenience too, that it may be easily procured, whereas good Quick-Lime is sometimes difficult to come at.

For fossil Acids, and volatile Alkali's.

Coating of
Vessels.

But in distillations, particularly in the hottest Furnaces, where the Vessels are red hot, it sometimes unluckily happens, that when you throw in new Fuel, either the cold Air, or the coldness of the Matter thrown in, strikes upon the Surface of the red hot Vessel, which then easily flies, and bursts asunder. Hence it is absolutely necessary, that these Vessels should be coated over with some proper Matter, in order to secure them from the ill effect of this sudden Cold. And this must sometimes be done likewise, when you distill with glass Vessels in the strongest Sand-heat, where the Glass is ready to melt; for by this means the Glass will be fixed as it were by this Crust, and be prevented being put in fusion. In order to make this in the best manner, take some Potter's Clay and Sand, reduce them to a Powder, and with some Water work them thoroughly into Paste, that is no longer tenacious, and then at last add a little Mason's Lime, and mix them well together. When you use it, warm your Vessel, hold it over the Vapour of Water, that it may be slightly moisten'd all over; then cover it intirely with this Paste, and by working it with your hands, reduce it every where to such an equal thickness, as you shall see convenient: This being done, sprinkle it over with hot dry Sand, and then set it by in a cool place, that the Coat may dry very slowly. If it should happen to get any cracks whilst it is drying, they may be stopp'd up with the same Matter. When these Vessels are prepared in this manner, they will bear a very intense Fire.

Of FURNACES.

Various Fur-
naces.

There is now, Gentlemen, but one thing more left to finish our Theory of Chemistry, and that is, a short consideration of Furnaces, which we shall now proceed to. And here we don't propose to describe all the Furnaces made use of in the management of Metals: Nor, indeed, is this necessary, since what the incomparable *George Agricola* has done upon this head is sufficient, who has explained this matter in the most elegant Style, and illustrated it with very accurate Cuts. If you will consult *John Rudolphus Glauber* too, upon Furnaces, you will find some particular contrivances for rendering some of the ruder Operations of Chemistry more easy. Of these things, therefore, I need say nothing. But it's my design here to explain to you those Furnaces, which a person will have occasion for, who has a mind to exercise himself in the practical part of Chemistry, according to the method of our processes.

The end
they answer.

A Furnace, then, is a Machine, by means of which, the Fire may be contained, confined, and applied to the Vessels, in which the Matter to be chang'd by the Fire is expos'd to it. In a Furnace, therefore, in the first place, there is required a *Focus*, or Fire-place, in which the Fire may be lighted, kept up, and determined. And as the Fire, which must be fed with proper Fuel, requires a Chimney to carry off its Smoke, and a Draught for the Air, and a Door to throw the Fuel in at, it appears in what manner these ought to be contrived. In the second place, in building a Furnace, we ought particularly to take care, that the direction of the Fire be so managed, that it shan't spend itself to no purpose, but shall be determined towards that part where we have occasion for it. And in the third place, it must be so built, that the Vessels containing the Bodies to be operated upon, may be so conveniently disposed,

as

as to be equably affected with any degree of Heat necessary, till the Operation is compleated.

That Furnace, therefore, will be best in its kind, which will perform the desired effects, with the least Expence, for the longest Time, and with the greatest Equability, and be managed with the least trouble and attendance of the Operator. The first of these ends will be answered, by contriving it in such a manner, that the whole Heat of the Fire, without any loss, may be apply'd to the Body under Examination. This will be obtained by building the Furnace of solid Materials, and forming the internal Surface of such a figure, as is proper to determine the strength of the Fire to the place designed: And this contrivance will have this advantage too, that the frequent attendance of the Person that keeps up the Fire will be less necessary. The second end will be answered, by chusing out such Fuel as will consume as slow as possible, so that it will but, at the same time, keep up such a Heat as is necessary for the Operation. And this is effected in particular by observing a proper proportion between the Fire-place, the Chimney, and the Air-holes: Upon which Principles, your skillful Operators will at once lay on such a quantity of Fuel, as will last for a very considerable time. The third circumstance, however, is the most necessary of all, *viz.* That the Fire may be kept up to the same degree, without any increase or diminution of its strength. For it appears by chemical Observation, that a determined degree of Heat produces upon every Body a certain effect; and hence, when the action of it grows either stronger or weaker, the effect will be different from what it was before. For this reason, therefore, there often arises a confusion among our chemical productions, when in the same Operation, we promiscuously make use of a greater or less degree of Heat. And besides, it is particularly to be observed, that such a variation of the Fire, makes Bodies of quite another disposition, with regard to any particular degree of Heat: For if in two chemical Operations, we make use of the same Fire, but let the degrees of Heat succeed each other in a different manner, we shan't be able to produce the same things from the very same Body; which has often prov'd a very detrimental error. In building of these Furnaces, therefore, the Workman must always consider first the quantity of Fire, which the Fire-place of the Furnace must receive, contain, and keep up. Secondly, the kind of Fuel to be made use of to answer the purpose; upon which head, you may consult what has been laid down from p. 168, to 214. In the third place, he must have a regard to the strength of Fire necessary for every particular chemical Operation: For the very same quantity, of the same Fuel, in the same Fire-place, may produce such various Heats, that by means of it, every intermediate degree, from the gentlest to the most intense, may be excited and continued: In the fourth place, therefore, he must always have a particular regard to the easy access of the Air to the Fire-place; and should take into his computation too, the strength with which the Air tends to the *Focus*, either by Blast or Draught. Nay, and he ought to consider too, the various states of the Atmosphere, with regard to Heaviness, Lightness, Moisture, Dryness, Heat and Cold: For when the Barometer is highest, and it freezes hard, and the Air is dry at the same time, the same Fire will burn brightest and strongest. But in the fifth place, he ought above all to attend to the course of the Fire that is kindled in the Fire-place: For if there

The quality
of the best
Furnace.

there are any large passages, by which it can make its way out into the Air, it will be dissipated, and lose its strength; whereas, if its united action is determined to that particular place where the Operator wants it, it will best of all answer his ends. These, then, are the fundamental Principles upon which depends the just construction of Furnaces. I shall, now, therefore, proceed to describe those Furnaces which I here make use of before you, and which a Person ought to have in his Laboratory, if he wou'd be furnished with such as may enable him to perform all the Operations of Chemistry. To begin, therefore, with the most simple, which I contrived for my own use above forty years ago, when I was making great numbers of Experiments in a Study not very large, and that had but a small Chimney, for which I had occasion for a good many Furnaces.

The most
simple Fur-
nace.
Pl. XIII.

This then is made in the following manner. With the best and driest Oak a hollow Prism is formed upon a square Base, 9 inches broad, and 14 inches high. Within this there is fixed a square Partition made of the same Wood, and an inch thick, which must be placed 5 inches from the bottom, and will by this means divide the Furnace into two parts, the lower of which will be 5 inches high, and is the *Focus* or Fire-place; the upper 8 inches, in which are placed the Retorts, or Cucurbits, for distillation. This middle Partition, which represents a kind of Diaphragm, has in the middle of it a round Hole of 5 inches diameter, in the hollow of which may be placed the round bottom of the Cucurbit, or Retort. And this too has four more round Holes in it, of an inch diameter each, that the Heat may rise out of the bottom-part into the top. The Fire-place has on one side a Door with Hinges, which is as big as the side of the Fire-place, viz. 9 inches wide, and 5 high, that it may be opened at pleasure, or shut close as there is occasion. The whole internal Surface of the Fire-place is lined with thin Plates of Iron or Brass, that so the Wood may be in some measure defended from the Fire. The Door likewise has four round Holes in it, each an inch in diameter, for the free admission of the Air into the Fire-place, to which there are fitted four cylindrical Stoppers, by the help of which you may let in more or less Air, as you find it necessary. And here the Carpenter must be particularly careful, that the Door be made of very dry Wood, and so fitted, as to shut the Fire-place up exceeding close. As for the upper part of the Furnace, the side contiguous to the Door below, has a Hole cut out in the middle of it, and reaching to the top, which is $4\frac{1}{2}$ inches square. On the inner edge of this Hole, the Wood is cut away all round to the breadth of half an inch, and to half the thickness of the Board of which the Furnace is made, and then on every side there is fastened a slip of Wood in such a manner, as to form a groove with that hollow. There is then cut out of the same Wood a Board an inch thick, and exactly of the same size with the Hole cut in the side, but that has likewise on its inner part a rim on all three sides, half an inch broad and thick, in order to slip into the groove formed on the edge of the Hole, that thus this Board being every way secured, may shut up this Hole exactly, when you have a mind to distill in a Cucurbit, digest in a Bolthead, or exhale in an open Vessel, and be removed again when you want to distill in a Retort: For which purpose you must have another piece made exactly in the same manner as the former, but only with a circular Hole in the middle of it, of $2\frac{1}{2}$ inches diameter, to trans-

mit

mit the Neck of the Retort. The top of the Furnace consists of two folding Doors, which in their middle are cut out into an orbicular Hole of 5 inches diameter, to let through the Cucurbit, or Neck of the Bolthead: And lastly, there is a round wooden Cover made fit to this Hole to stop it close, when you distill with a Retort. When you want to set it to work, take a square earthen Pan with 3 feet, $\frac{1}{2}$ an inch high, whose bottom must be plain, and its sides on the outside $5\frac{1}{2}$ inches wide, and the height of the whole Pan, from the bottom of the feet to the edge of the Pan, 3 inches and a half. On the bottom of the Pan, spread lightly some sifted Ashes to the height of a quarter of an inch, and then upon this lay a Live-coal of *Dutch Turf*, perfectly red quite through, and not at all smoaky; and then this, if it is lightly sprinkled over with the same sifted Ashes, will keep up such an equable Heat for near four and twenty hours, as the human Body is capable of bearing. But here you must take notice, the thinner the Coal is covered with Ashes, the greater will be the Heat, but then it won't last so long. In this Furnace, now, you have neither Smoke nor Smell. And it maintains such a very soft equable heat, that I can't think but that Eggs might be hatched in it. But in this too we can raise as great, nay and greater degree of Heat, than that of boiling Water. In this, therefore, conveniently, safely, and with little expence, may be performed all Digestions, distillations of Waters, spirituous Liquors, volatile alkaline Salts, and all volatile aromatic and oleose Salts, as well as all Preparations of Tinctures. All exsiccatations, and exhalations for the formation of Chrystals, may be affected here likewise. Nay, after *Glauber's* manner, I have prepared in it Spirit of Nitre, and Spirit of Salt, to the great surprize of an old experienced Chemist. This therefore I call the (*Furnus Studioforum*) Student's Furnace.

But when you want a Furnace that will yield a greater Heat for distillation in Sand, then the following seems to me the best fitted for this purpose: And as the portable ones have this convenience, that they leave the common Fire-place free, I'll describe one of that sort. With a very thin Plate of Iron, make a hollow Cylinder 17 inches in diameter, and 19 inches high. Let the bottom be closed with a Plate of the same kind, and the top be open. Let it be supported at bottom with 3 iron Legs 12 inches long, and let the inside of the bottom be covered with a copper Plate, that the Salt of the Ashes mayn't too soon eat away the Iron. Within the Cylinder, you must fix a Grate parallel to the Base, whose upper surface must be 4 inches above it. Let this Grate be surrounded with a thin Rim $3\frac{1}{2}$ inches broad; and let the Bars be $\frac{1}{2}$ an inch square, and stand an inch from one another; or let the diameter of the circle of the Grate be so divided as to place six such iron Bars in it. This Grate is placed within the iron Cylinder at 4 inches distance from the bottom, where it must have three pieces of Iron standing out to support it. Let your Door then to this Ash-hole be 4 inches high, and 6 wide, and made to fit nicely, that it may shut it up very close upon occasion. Three inches above the upper surface of your Grate make the opening of your Fire-place, which must be 6 inches wide, and 4 and a half high. With the *Foci* then 15 inches distant, and a perpendicular from the *Focus* to the Circumference of 5 inches, describe an ellipse; and then by this make a solid wooden Semi-ellipse, cut off at the *Foci*; by which model you must shape the internal surface of your Furnace, which must be built with Bricks, so disposed, as to form such a concave surface,

Second Furnace.

Pl. XIV.

surface, and so contrived, that the edges next the internal part may come as close to one another as may be, so as to leave but small spaces, which must be filled with Mortar made of Lime and Sand. But before the Bricklayer can do this, you must have a Stopper made to the Fire-place. This must be made of a plate of Iron, the same of which you make your Furnace, and with the same cylindrical surface. As for the size of it, it must be made in such a manner, that when it is applied to the opening of the Fire-place, it may reach an inch beyond it on every side, that it may thus intirely close it up. Upon this Cover, then, you must erect a hollow Segment, cut out of this Cylinder to the size of the opening of the *Focus*, the sides of it tending towards the center of the Cylinder, and the top and bottom being parallel to the Base of the Furnace, that the internal surface of this Stopper may be made to answer to the concave, elliptical figure of the Furnace. Let the Bricklayer, then, fill this hollow with Brick and Mortar, and so form and smooth its internal surface, that when it is fixed in the hole it may make one continued, uniform figure with the surface of the Furnace. When this is made, build your internal Furnace with Brick and Mortar, in the manner before directed. At the upper part of the iron Cylinder, and on that part which is near to the door of the Furnace there must be a Segment cut out, 3 inches broad, and 2 deep, that the Neck of the Retort may be placed there in a declining position, when you have occasion to distill in such Vessels. And last of all, in the upper part of the Furnace an Iron Pot must be so firmly fixed in with Mortar betwixt the Bricks, that the Fire shan't be able to make its way through, but at the same time, about the edge of the brick-work, at top, there must be left 4 holes, shap'd like a Half-Moon, an inch broad, and two inches in curvature, which may serve as a vent for the Smoke and Fire. A Furnace built in this manner is fit for distillation with a Cucurbit, Retort, and Bolthead, and as it is portable, it is convenient for a great many purposes.

A Third
Furnace.

Pl. XV.
Fig. I.

The third Furnace which an Elaboratory cannot be without is a *Balneum Mariæ*. This consists of the same Furnace as the preceding, except that the surface of the Grate is only 8 inches distant from the bottom of the brass cylindrical Vessel. The brass Vessel which is for the Bath, and is set with Mortar within the upper part of the Furnace, is 12 inches deep. This is of a cylindrical form, and at the top has a horizontal Rim an inch broad, by which it rests upon the top of the Furnace, and above that, another of the same breadth rising perpendicularly. There is then another Vessel made, in such a manner, that when it is placed within the former, it may stand an inch distant both from its bottom and sides, and may reach 5 inches above the top of the furnace. At 12 inches distance from its bottom, this Vessel has a rim on its outside, which runs a little declining, and when it is just broad enough to cover the aperture left between the two Vessels, is turned perpendicularly downwards, that it may be received exactly within the erect, perpendicular Rim of the former, and thus the cavity between them may be perfectly closed. In the broad, lateral Rim of this Vessel there is a hole made for pouring Water into the Bath Vessel, that by this means it may be contained betwixt that Vessel, and this internal one. The Neck of this second Vessel receives into it an Alembic, whose *Rostrum* may be inserted into a Tin Worm, in a Refrigeratory. To this likewise may be fitted that sort of Alembic, which is produced into a tall, cylindrical Tube, and then turned down again, for the distillation

distillation of Alcohol, which we have already described. And lastly, there may be made a Cover to the Bath Vessel, to fit into the perpendicular Rim, as the former did, and close it in the same manner. And the Neck of this Cover, too, may admit an Alembic, in order to distill with a Worm. This Furnace, then, thus compleated, we may make use of first, for the common distillations of all Vegetables with Water; and of all Resins, Balsams, and Gums with Water, into their essential Oils. Secondly, for distillation of Vinegar; and very conveniently for distilling any thing whatever either in *Balneo Vaporis*, or *Maris*, in any determined degree of Heat, as far as the degree 212. And thirdly, this is of excellent service in the preparation of Alcohol at once, with a good deal of ease, and in a large quantity, which otherwise requires so much Time, Fire, Labour, and Charge. For these reasons, I have in Plate XV. given you a very exact description of it, with its whole *Apparatus*.

But there is still wanting a Furnace, in which may be raised a very intense Heat, for fusing Bodies that require a very strong Fire. And this is best built in the following manner. In the first place, let there be raised a stone Base, arched at top, and 3 feet high; for this Furnace must have the Door of the Fire-place at such a height, that the Operator may look into it as he stands upright. Upon this Base let there be raised an Ash-hole 5 inches high, and over this a Grate, with Bars almost an inch thick, and near an inch from one another. Let the Base of the Ash-hole, and the Grate above, be of a circular figure, and 12 inches in diameter, and above the Grate let the Cylinder be continued to the height of 6 inches. Upon this Cylinder let there be erected a paraboloid Cone, whose *Axis* must be 8 inches, and lowest ordinate 6, whence its Parameter will be 4 inches and a half, and its *Focus* one inch and $\frac{1}{8}$ from its *Vertex*. When this Paraboloid is built to 6 inches height above its cylindrical Base, raise a cylindrical Chimney over it 2 feet high, whose diameter will be 3 inches. In the fore part of the Fire-place 2 inches above the Grate, let there be a door 5 inches wide, and 6 high, and arched above with the arc of a circle of 12 inches diameter. At an inch distance above the arch of the door let there be a conical hole in the Furnace of 2 inches aperture, that you look down through it into the Fire-place if you want to see whether the Matter is melted in its Vessel; and make a Stopper to put in or take out of this hole at pleasure. This Furnace must be built of very good Bricks and Mortar, its walls must be 5 inches thick, and its internal surface must be smooth'd over with very dry Lime. This, when it is once hot, raises a prodigious Fire, especially in the middle of the *Axis*, and the upper part, as is demonstrated geometrically with a great deal of ease. The iron door must be let in so as to shut very close; and the bottom of the Ash-hole must be a plate of Iron, that if any thing happens to fall through the Grates it may readily be come at again.

Fourth Furnace.

Pl. XVI.

But a chemical laboratory must be still furnished with another Furnace for the distillation of acid Salts, from Nitre, Sea-Salt, Fountain Salt, *Sal-Gem*, Vitriol, Copperas, and Alum. This then, after having tried various sorts of them, we build after the following manner. Upon the pavement under the Chimney let there be erected a Parallelipiped, the breadth of it in the front 20 inches, and length 38; and the breadth of its cavity in the front 12 inches, and its length 22; whence the thickness of the Wall is evident. Let this Parallelipiped

Fifth Furnace.

Pl. XVII.

U u u

Parallelipiped

paralleliped be raised 11 inches high. In the middle of the front let there be an opening carried from the Pavement 11 inches high, and 4 broad, round the edge of which let the brick-work be let in a little, that a door, made of an iron plate may be received into it, when you want to stop it close: This is for the Ash-hole, and draught to the Furnace. Here, instead of a Grate, let there be fixed some prismatical iron bars, an inch square, 14 inches long, and an inch distant from one another, and let them lie parallel with the breadth of the Ash-hole. Upon the upper hollow of the Paralleliped let there be described an Ellipsis, whose *Foci* must be 22 inches distant, and transverse Diameter 12, and then the breadth of the Fire-place at the beginning and end will be nearly 10. With this elliptical Figure then let there be a cavity formed, within 4 inches and a half deep, and let the external parts be compleated in a parallelipedal form. In the front Wall, directly over the Ash-hole, let there be an opening into the Fire-place, 7 inches broad, and 9 high; and let this Hole have its lower edge declining inwards 1 inch and a half, and have an iron Door made exactly to fit it. Let the lower part of the Door be 3 inches above the upper part of the Ash-hole. In the other longer side there must be an arched aperture, whose lower limb must be placed 10 inches above the Grate. The length of this Limb must be 20 inches, its height 12, and the Arch must be an Ellipse, whose *Foci* are 20 inches distant, and has a transverse Diameter of 24. At this aperture are put in the long Necks. On the inside of the Wall, opposite to this aperture, and 9 inches above the Grate, there must be raised a Ledge of an inch and a half breadth for the Vessels to rest upon during the distillation; and in the middle of the same Wall at top there must be a square Hole for a Chimney, 3 inches broad, and 2 high. This being done, you must build the uppermost elliptical arch of your Furnace, whose vertical point must be 21 inches distant from the Grate; the *Axis* of the Ellipse 22 inches, and its transverse diameter 10. This Arch, therefore, will be formed by the rotation of such an Ellipse about its *Axis*, supposing this to be 16 inches from the Grate. When you distill in this Furnace, you take 2 Long-necks, 11 inches high, 9 wide, with cylindrical Necks 5 inches long, and $3\frac{1}{2}$ diameter, and place them horizontally, and parallel, so that their bottoms shall rest upon the Ledge in the opposite Wall, their mouths being parallel to the aperture they lie in. With Bricks, and Mortar, then, you close up intirely the whole aperture; and to the mouths of the Long-necks apply a cylindrical Tube, and to that a Receiver. With such a Furnace as this you may raise an incredible heat. It is safe, and easily managed; and makes the Fire exert all its strength upon the distilling Matter alone; and by means of the Ash-hole, it is easily regulated.

Other Furnaces.

The assaying Furnace is so plainly describ'd by the industrious, candid *Lazarus Erker*, that there is no room to add any thing upon this head; and a very accurate cut of it you may see in *George Agricola*.

And as for the Furnace with the *Vesica*, Alembic, Worm, and Refrigatory that is too well known to need any description. I may now, therefore, dismiss this subject too, and thus put an end to the first and second part of these Institutions.

The Explanation of the P L A T E s.

P L A T E I.

FIG. 1.

AB, CD. Two cylindrical iron Rods three feet long.
E. A Ring with a handle F, whose cavity measures exactly the thickness of both Rods when they are cold.

FIG. 2.

AC, BD. Two parallel Plates, divided into very small equal parts.
AB, CD. Two parallel Plates, which may be moved up and down by means of two Grooves, in AC and BD.
EF. The iron Rod to be measured when it is cold, and after it is heated.

FIG. 3.

AB. A brass Ruler divided into very small parts.
BC. Another, perpendicular to the former at B, graduated with very minute, and equal divisions.
AD. A third fixt upon an Axis at A, so that it may move upon the Ruler BC, and by this means may give you the number of parts upon BC, that the Rod made red hot, and set upon a certain point of AB, will elevate the Hypothenuse AD, higher than it did when it was cold, and plac'd upon the same point.

P L A T E II.

FIG. 1.

ABDC. The common Thermometer of *Drebbelius*.
A. Its hollow Sphere.
BD. The Neck full of Air to D, with which the Sphere is filled likewise.
DC. That part of the Neck that is filled with a colour'd Liquor.
E. A Vessel containing the same Liquor.

FIG. 2.

AB, DC, EF. A Thermometer of *Drebbelius*, more sensible than the former.
ABCD. An anterior view of the same.

FIG. 3.

ABCDEF. The same seen sideways; that the Segments of the Sphere of which the upper Cavity is formed, may come in view.

U u u 2

P L A T E III.

P L A T E III.

FIG. 1.

- A. A smaller Sphere, in which the contained Fire expands itself equably.
 B. A larger Sphere concentric to the former, and including it, into which the Fire diffuses itself equally out of the other.

FIG. 2.

- AFIG, BDIE. Two equal Spheres touching one another in the point I.
 CD. A right Line drawn from the Center C, of the first Sphere, which is a Tangent to the other at D.
 CE. A right Line drawn from the same Center C, touching the second Sphere at E.
 CFG. The Sector in which is contained that part of the Fire in the Sphere A, that may be equably communicated to the Sphere B, the proportion of which being found to the whole Sphere, shows what quantity of Fire thus equably expanding itself from the Center of one Globe can fall upon another of the same Magnitude in contact with it.

FIG. 3.

- A, B. Two Spheres equal to the former, and in contact.
 C. The Center of the Sphere A.
 D. The Center of the Sphere B.
 K. The point of contact of the Spheres.
 CKD. A right Line joining their Centers.
 EG. A Line parallel to CKD, touching both Spheres.
 FI. A Line parallel to EG, touching them both likewise.
 EFGI. The Cylinder through which all the Fire of the Sphere A being directed in parallel Lines, falls intirely upon the Sphere B; which therefore collects all the Fire that was before diffused through the whole superficies of the Sphere A: Whence the Fire will be four times denser in the Circle GDI, than it was in that Superficies.

P L A T E IV.

PLATE IV.

FIG. 1.

ABCD. A hollow Cylinder made of Iron Plates, and open at both ends, which is the Fire-place of the Machine.

BD. Its lower aperture where it communicates with the other Cylinder, by means of a Grate.

EFG. A hollow Cylinder made of the same Iron turn'd up at F, shut at E, and open at BD, where the Grate is, and at G, where the invisible Smoke passes out.

FIG. 2.

ABCDEF. A hollow Parallelipiped open at ABCD, in which the Fire-place is at ILKM.

ILKM. The Grate of the Fire-place, upon which is laid the combustible Matter.

EM. The place under the Grate into which the Flame and Smoke are depressed as soon as ever the Tube OGH grows very hot.

NO. The aperture, which is here square, but may likewise be made oval as in the Text. If it is made square, it must be a little narrower than KM, if elleptical, its Diameter must be of that length.

NOGH. A hollow Tube of the same Iron, either parallelipipedal or elliptico-cylindrical, as in the Text, open under the Grate at NO, and at the top H.

FIG. 3.

ABC. The biggest Glafs-Receiver I could get, open at C.

AB. The bottom of it cut out in a circular form, and therefore open there too.

D. A brass Cylinder in which the Liquor being set on fire gives the Flame H, confined under the Bell.

EFG. Three Bricks which the Bell is set upon, that the Air may have free admission to it underneath.

FIG. 4.

ABC. A glafs Vessel, as before.

E. A Pan with a live Coal.

D. A brass Dish, in which the Alcohol burns, the Dish standing upon the Coal.

F, G, I. Three Bricks on which the Glafs stands.

H. The Flame of the Alcohol set on Fire under the Bell.

PLATE V.

P L A T E V.

FIG. 1.

ABC. A Thermometer fixed to the board DEFG by the brass rings M, N, O.
DEFGHIKL. A wooden Machine made to stand upon a table with the Thermometer.

PQ. A vessel in which the Bulb of the Thermometer may be placed, and then any liquors, you have a mind to make trial of, may be poured in successively and mixed together.

FIG. 2.

ABC. *Fabrenheit's* first Thermometer, which by the dilatation of the tinged spirit indicates the increase of the heat of the Atmosphere.

AB. Its Bulb, which in the greatest observed natural cold contained 1933 parts of tinged spirit, of which the Pipe BC contained 96.

BC. A Pipe produced from AB and by a Scale fixed to it divided into 96 equal parts, that the spirit when it dilates, and ascends, may discover the augmentations of Heat.

FIG. 3.

ABC. *Fabrenheit's* second Thermometer measuring the increments of Heat in the Atmosphere by the dilatation of Mercury.

AB. Its Bulb, which in the greatest observed natural Cold contained 11520 parts, of which the Pipe BC contained 96.

BC. A Pipe produced from AB, and divided by a Scale into 96 equal parts, by which the Mercury when it ascends determines the increase of Heat.

FIG. 4.

AB. *Fabrenheit's* third Thermometer to measure the Heat of the Human Body.

AB. A clear glass Tube, perfectly closed hermetically, within which it is placed.

DC. The Thermometer within, either by its tinged spirit, or Mercury, indicating the increments, or decrements of Heat.

DE. Its Bulb.

EG. Its neck.

EF. The fluid in the neck, by its ascent pointing out the Heat, by its descent the Cold.

EFG. A paper divided into equal parts or degrees.

This Thermometer being held a good while under the arm, upon the breast under one's clothes, or in the mouth, will determine the Heat of the Body at that time.

P L A T E VI.

P L A T E VI.

ABCD. A brass Plate hollowed at vxyz that the Bulb of the Thermometer may be let into it.

EF. A Thermometer made with Mercury in such a manner, that in the greatest observed natural cold the Mercury may stand at I, and in the heat of boiling Mercury at F.

GE. The Bulb of the Thermometer.

GF. The pipe of the Thermometer divided by means of the brass Plate into 600 equal parts, which in this short Figure cannot be all represented distinct, and therefore here we have divided it into larger portions IK, KL, LM, &c. each containing 65 of such equal parts.

G, H. Two brass Semi-circles by which the Thermometer is so fixed to the Plate, that you may take it off whenever you please.

abcd. A brass vessel, into which the Thermometer may be put when taken off of the plate, that the heat of the Liquor to be examined, whilst it boils in this Vessel may be marked upon the neck GF, which then being applied to the Scale, will give you the degree desired.

FIG. 2.

A. A hollow cylindrical Vessel open at a, quite full of water, but its mouth covered with the paper D, which is then inverted without any Water running out. The same Vessel covered in the same manner, and lying horizontally, without any Water running out.

B, B. Conical Vessels, with which the Experiment succeeds in the same manner, as it does likewise in

C. A small Bolthead.

PLATE VII.

P L A T E VII.

FIG. 1.

- ABbc. A strong glass Tube every where equally wide.
 AB. The longer Leg, some feet high.
 bc. The shorter, 12 inches high, and nicely divided into lines.
 A. The Mouth at which the Mercury is poured in.
 c. The extremity hermetically sealed.

FIG. 2.

- ABC. A very small Bolthead filled with Water and inverted.
 BC. The Bulb, at whose top C is contained the Air, which entering in the form of Bubbles ascended and burst asunder.
 AB. The Neck, whose orifice A is 5 lines diameter.
 A, d, e, f, g, h. Bubbles, in which form and size the Air admitted into the Neck is collected and ascends, not mixing with the Water, but associating into a large Body.

FIG. 3.

- ABC. A Glass like the former, full of Water, and inverted.
 BC. The Bulb still full of Water.
 BA. Its Neck, whose Mouth A is 8 lines in diameter.
 d, e. Large Air-bubbles, in which form and size the Air enters and ascends without mixing with the Water.

FIG. 4.

- ABC. The same sort of Vessel in a horizontal position, and full of Water.
 d, e. Large Air-bubbles, which continue thus a good while in the Water, without dividing.

FIG. 5.

- AB. A narrow glass Tube open at both ends.
 Ac. Water in which the part Ac of the Tube is immersed.
 cD. Water ascending in the Tube spontaneously.

PLATE VIII.

FIG. 1.

A, B, C. Three glass Vessels with Water of different degrees of Heat.
DHEI. The brass Plate joined to the Tube KL of the Air-pump.
FGMN. The Bell that stands upon this Plate and covers the Vessels A, B, C. from under which the Air is exhausted by means of the Tube KL.

FIG. 2.

AB. A cylindrical glass Vessel, with a plain bottom B.
CD. A glass Bottle, whose Belly C may be placed within the Cylinder AB, that its mouth D may rest upon the bottom B.

FIG. 3.

AB. A cylindrical hollow Vessel open at A, with a plain bottom B, and filled with Water.
BCD. A Funnel open at D, whose upper part ED is inserted into the neck EG of the Bolthead EGF.
EGF. The Belly and Neck full of Water.

FIG. 4.

AB. A parallelipedal brass Vessel.
B. A plain bottom, which at C has a cavity impressed in it, in which there is placed a drop of Water not boiled.
D. A conical glass Vessel, whose base is so large that it can surround the Cavity C.
E. The Conoid plac'd over the drop of Water in the cavity.
F. The same lying upon its side whilst the Oil boils, that the Air may be expelled, and the Oil may enter.
G. A lighted Candle, placed under the cavity in which the Water lies under the Oil.

X x x

PLATE IX.

P L A T E IX.

FIG. 1.

AB. A brass Cylinder.

B. A hole in AB, into which the Tube BCD was foldered.

AE. A Cock fixed in AB, by which all the Air might be let out of the upper part AF, as the Water rose in the Cylinder, and which might be shut when that was perfectly full.

BCD. A brass, hollow, cylindrical Tube opening into the Cylinder at B, and open above at D, so that the Cylinder AB might be fill'd with Water, by pouring it in at D.

FIG. 2.

AB. A steel Cone divided into equal parts.

CD. A hollow wooden Cone, which, when dry in a certain degree, would just admit the Cone AB within its cavity.

FIG. 3.

ABCD. A cylindrical Vessel made, as they call it, of double Glass.

BCE. The bottom of the Vessel rising a little inwards in the middle.

FGHI. The neck of the Vessel, with the cylindrical Mouth HI, an inch and a half in diameter.

KL. A Rim round the Mouth, for dropping out the Liquor, which would otherwise run down the sides of the Neck.

MN. A glass Stopper whose cylindrical part N is exactly ground to the Neck of the Vessel HG. M. the Top of this, thick and flat.

QROP. A Vessel contrived for the more valuable Oils.

FIG. 4.

A, B, C. A Crucible, and Vessels made use of for fixed Bodies in the Fire.

PLATE X.

FIG. 1.

ABCDEF. The true figure of a distilling Vessel, called a Cornute, or Retort.

ABCD. A hollow Sphere, the Belly of the Retort.

AF. A Tangent to the Sphere in the Vertex A.

DE. A right Line parallel to the Tangent AF, drawn from the point D, where the Diameter parallel to that Tangent cuts the Sphere.

Of these three forms, the last is the best.

FIG. 2.

ABCDE. A Vessel contrived for the distillation of the most fixed Bodies, as Phosphorus, &c.

FIG. 3.

ABCDEFGH. A Long-neck to be placed horizontally in the Furnace, so that the mouth may be a little way out.

IKLM. A hollow, cylindrical Tube, one of whose ends may be received into the mouth HG of the Long-neck, whilst the other is inserted into that of the Receiver ON.

ONPQ. A very large Receiver, which being placed horizontally receives the extremity LM of the cylindrical Tube.

X x x x

PLATE IX.

P L A T E X I.

FIG. 1.

ABCD. A Tin Cylinder 6 inches wide, ending in
CDE. A Conical Tube 4 feet high, and an inch in diameter at the vertex E.

EF. A cylindrical Tube 4 feet long, and an inch wide.

FG. The same produced, that it may be inserted into the mouth of the Worm in the Refrigeratory.

HIK. Holdfasts to keep the ascending and descending Tubes tight together.

This is the Head used in the Distillation of Alcohol.

FIG. 2.

Glass Vessels so contrived as to fit into one another, by luting which together, you may increase the distance between the distilling Vessel and Receiver, to what length you please.

FIG. 3.

A Pelican.

FIG. 4.

A more compendious Pelican with two Boltheads.

P L A T E X I I.

FIG. 1.

The whole Apparatus as used in distilling.

ABCDEFGH. The earthen Long-neck placed horizontally in the Furnace.

IKML, A hollow cylindrical Tube inserted into the mouth of the Long-neck HG, and that of the Receiver ON.

ONPQ. The Receiver.

FIG. 2.

A chemical Vial, Bolthead, or Matrafs.

FIG. 3.

The biggest Receiver the workmen could blow, which fort the Chemists now-a-days make use of.

P L A T E X I I I.

PLATE XIII.

The First Furnace.

- AB. One side of the square base 9 inches long.
 AB EF. The square base.
 ACBD. The height and breadth of the prismatical Furnace, which is 14 inches high.
 AI, BK. The height of the Fire-place 5 inches.
 IL KM. The thickness of the partition 1 inch.
 LC, MD. The height of the upper cavity of the Furnace 8 inches.
 PP. A circular hole 5 inches in diameter cut out in the middle of the Partition, in which is placed the bottom of the Cucurbit, Retort, or Bolthead, and whose upper edge is par'd away.
 QQQQ. Four smaller circular holes in the same, each an inch in diameter, made to transmit the heat from the Fire-place into the upper part of the Furnace.
 fghi. A square hole cut in the upper part of the side BDHF, the same letters representing the square board that fits into it, and is in the Plate placed on the side of it.
 fp, gp, kp, ip. The edge of this board cut away to half its thickness, which is to be put into the hole gH, hD, when you distill with a Cucurbit.
 klmn. Another square board exactly like the former, but with a circular hole in the middle O, of $2\frac{1}{2}$ inches diameter, to be used when you distill with a Retort.
 fg, hm. Each $5\frac{1}{2}$ inches.
 RSTU. The door by which the Fire-place is exactly closed up, which rises to the middle S of the Partition KM.
 XXXX. Four round holes in the door, to let the Air into the Fire-place.
 Z. Wooden Stoppers to fit into those holes to regulate the Fire.
 Cb Da, Gd Hc. Two folding Doors, which are so cut out in the middle, that when they are shut, they form a round Hole of 5 inches diameter tt.
 q. The Pan used in this Furnace.
 r. The Handle.
 s, s. The Feet.

PLATE XIV.

P L A T E XIV.

Second Furnace.

- AC, BB. Iron Feet 12 inches long.
 CNOD. The bottom of the Furnace, being an iron Plate covered with a brass one 17 inches in diameter.
 CGHD. A hollow iron Cylinder upon the Base CNOD, 19 inches high.
 ELMF. The Grate consisting of an orbicular iron rim, and the bars in the middle y, which is supported by the bars E F, and is parallel to the base CNOD.
 FL, MF. The breadth of the rim of the Grate $3\frac{1}{2}$ inches.
 EC, FD. The distance of the Grate from the bottom 4 inches.
 NOPQ. The door of the Ash-hole, 6 inches broad, and 4 high.
 QR, PS. The distance of the door of the Fire-place from the upper part of the Grate 3 inches.
 RSTV. The opening into the Fire-place, 6 inches broad, and $4\frac{1}{2}$ high.
 ILKM. An Ellipse whose ordinates at the *Foci*, LM IK are 5 inches long, from which is formed the elliptico-conoidal, internal surface of the Furnace, by the rotation of the wooden pattern bc de, upon the axis cb.
 a. The Stopper of the Hole of the Fire-place seen side-ways.
 Z. The same seen from above.
 KHY. A Segment cut out for the Neck of the Retort to lie in.
 IKX. A Pot 10 inches wide, and 5 deep.

P L A T E XV.

PLATE XV.

Third Furnace.

FIG. 1.

- AB. The breadth of the Ash-hole 10 inches.
 AC. Its height 6 inches.
 EC. Its thickness 1 inch.
 EI. The distance of the bottom of the Vessel from the Grate 8 inches.
 IG. The height of the Vessel 12 inches.
 LG. The rim of the Vessel, which rests upon the top of the Furnace, and is 1 inch broad.
 GM. A perpendicular rim to receive into it the rim of the Vessels, Fig. 3. 4.
 EGHF. The interiour elleptico-conoidal cavity of the Furnace, the distance of whose *Foci* is 20 inches, and a perpendicular to the axis at the *Focus* 5 inches.

FIG. 2.

- A brass Vessel, either to distill with, or to serve for the bath of the Furnace, Fig. 1. The letters the same as before.

FIG. 3.

- A brass Cover, whose Rim PQRS fits exactly into the Rim MOGH of Fig. 2. R, S. Two Handles.
 RT. SV. The middle of the Cover rising obliquely to be produced into TX, VY. A cylindrical Neck to receive the Alembic.

FIG. 4.

- A tin Alembic, whose Rim a b fits exactly into the Rim x y, and head ends in the *Rostrum* cde, the extremity of which may be inserted into the mouth of the Worm in the Refrigeratory.
 If, therefore, the Vessel GK is perfectly closed with the Cover py, and that with the alembic, and is fitted into the Furnace, then in this Vessel you may distill any thing with Water and a Worm, as likewise Balsams, Turpentine, &c.

FIG. 5.

The Vessel for distilling in *Balneo Mariæ*.

- fg ML. The Vessel in which the Bodies are put that are to be distilled in *Balneo Mariæ*, which is made so as to go into the Vessel GK, Fig. 1. its Rim KL being fitted exactly to the receiving Margin MO. In the surface of the Rim KL there is a Hole, by which you may pour Water into the Vessel GK. If therefore the Vessel f I is fitted to the Rim MO, then the Water boiling in GK, will distill in *Balneo* through the Vessel f I, the Alembic abc, Fig. 4. being fixed into the Rim HI.

FIG. 6.

- A tin Alembic described Pl. XI. whose Margin op being exactly fitted into the Rim HI, Fig. 5. serves for the distillation of Alcohol, the common Spirit of Wine being in the Vessel f I.

PLATE XVI.

P L A T E XVI.

Fourth Furnace, which is the melting Furnace.

abcd. A hollow stone Base arched at cd, and 3 feet high.

cdef. The Ash-hole, plain at bottom, and 5 inches high.

efih. The Grate.

ab, cd, ef, hi. 12 inches each.

hk, il. The Fire-place 6 inches high to kl.

kmnl. A paraboloid Cone, whose Axis is 8 inches, and inferiour ordinate 6 inches.

mnp o. A cylindrical Chimney 3 inches wide, and 2 feet high.

au, y4, bx, z3. The thickness of the Stone-work of the Furnace 5 inches.

P L A T E XVII.

Fifth Furnace.

FIG. 1.

AB. The breadth of the Furnace 20 inches.

AH, IB. Each 8 inches long.

HI. The breadth of the Ash-hole 4 inches.

HK, IL. The height of it 11 inches.

KM, LN. The distance of the Door of the Fire-place from the Ash-hole 3 inches.

MN, OP. The breadth of the Door 7 inches.

MO, NP. The height 9 inches.

BG, DF. The length of the Furnace 38 inches.

QRS. The Aperture in the middle of the side to place the Long-necks in.

QR. The length of the Limb of this Aperture 20 inches.

US. The height of the middle of it 12 inches.

ST. The thickness of the upper Wall of the Furnace 6 inches.

FIG. 2.

AB. A little brass Furnace for our first process, in which there is fitted a brass Plate, just at the top of the door of the Fire-place B.

CDEF. A tin Alembic fitted to the upper Rim of this Furnace.



FIG: I.

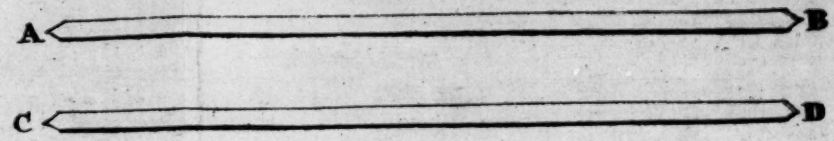


FIG: II.

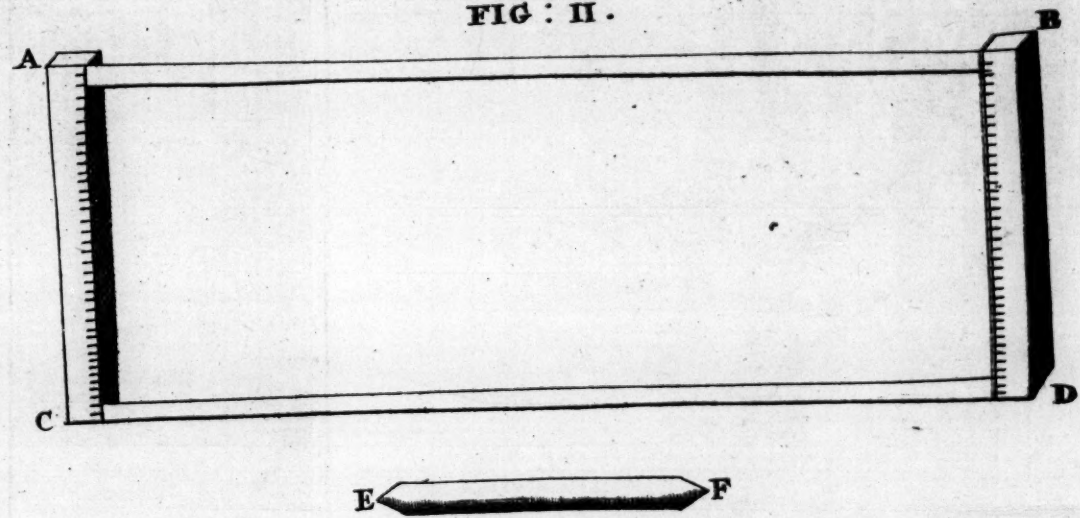


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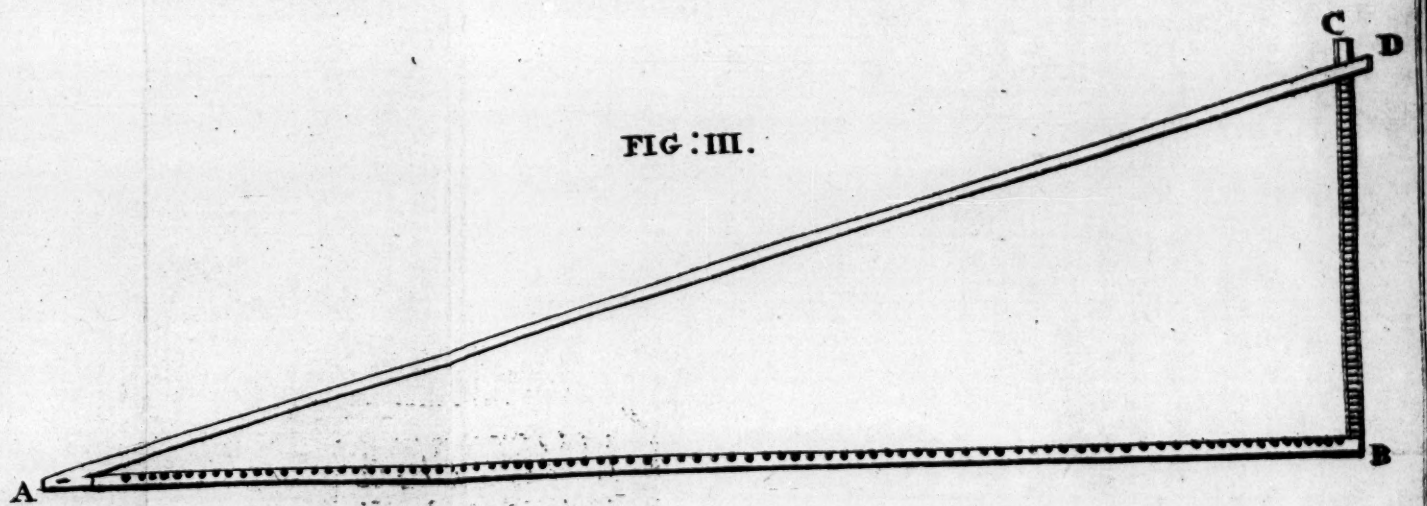


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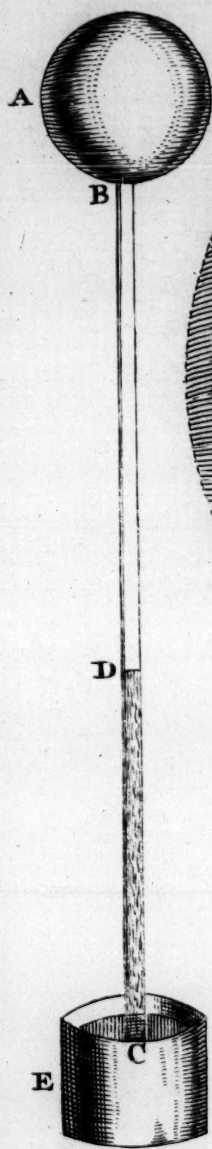


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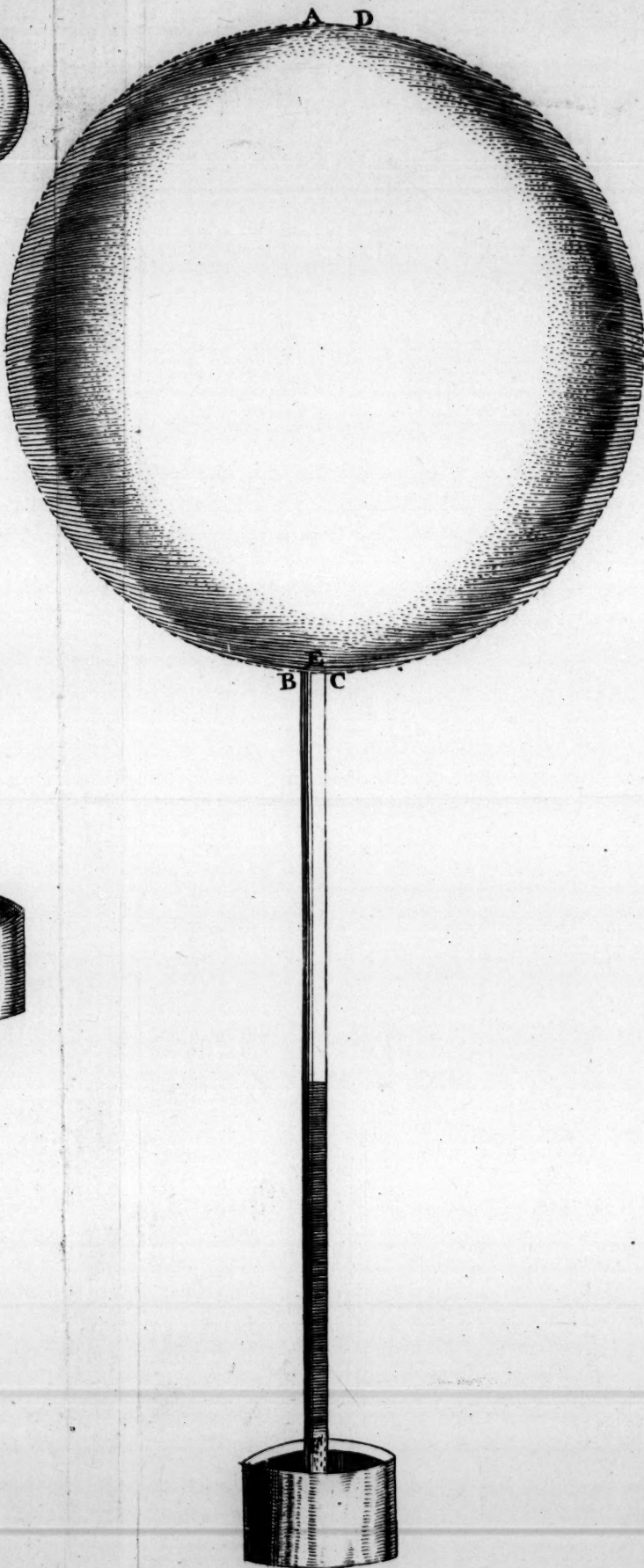


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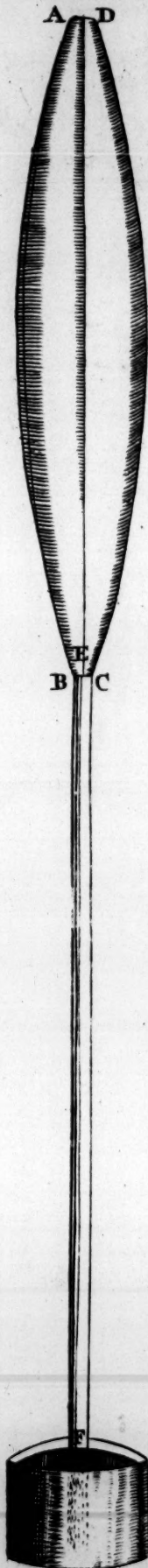


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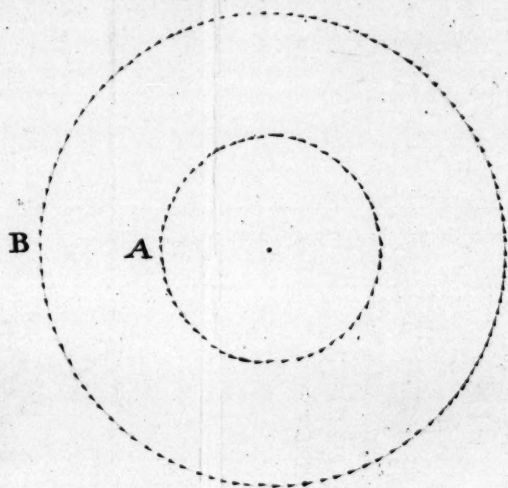


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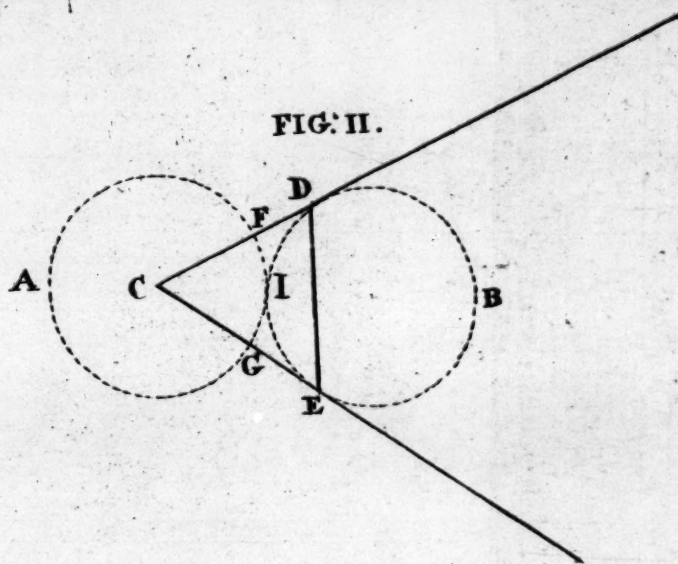


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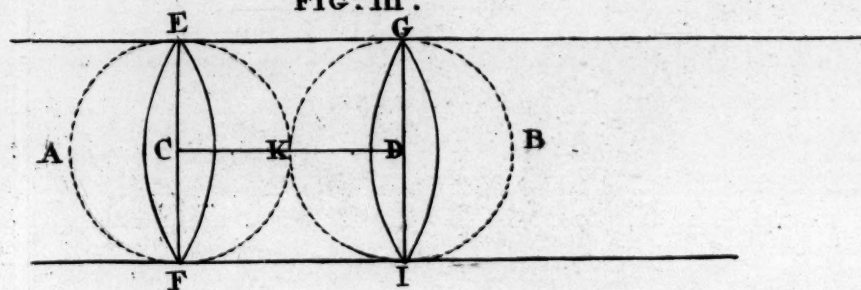


FIG. I.

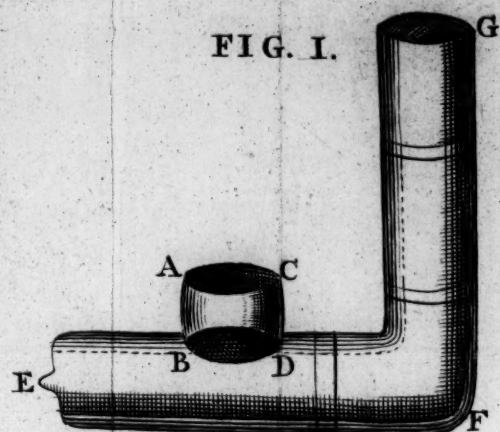


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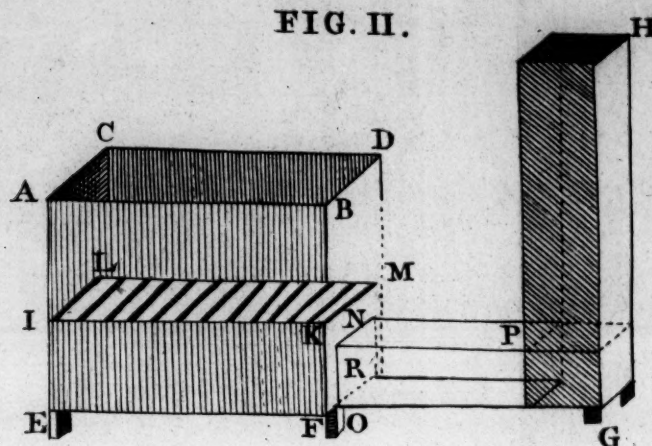


FIG. III.

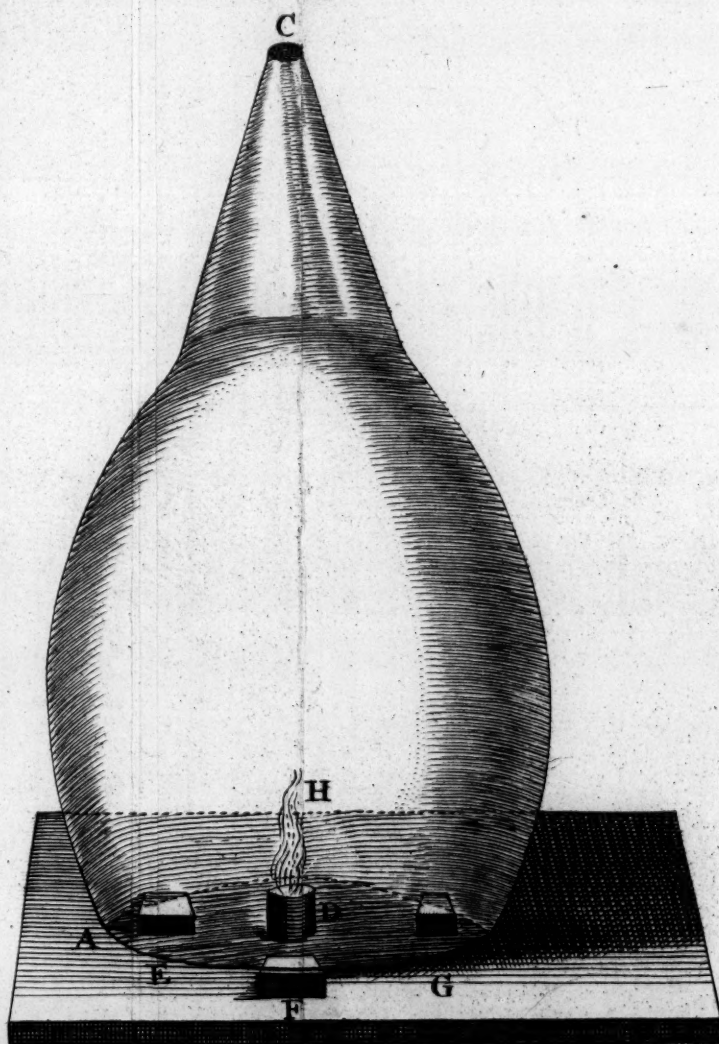
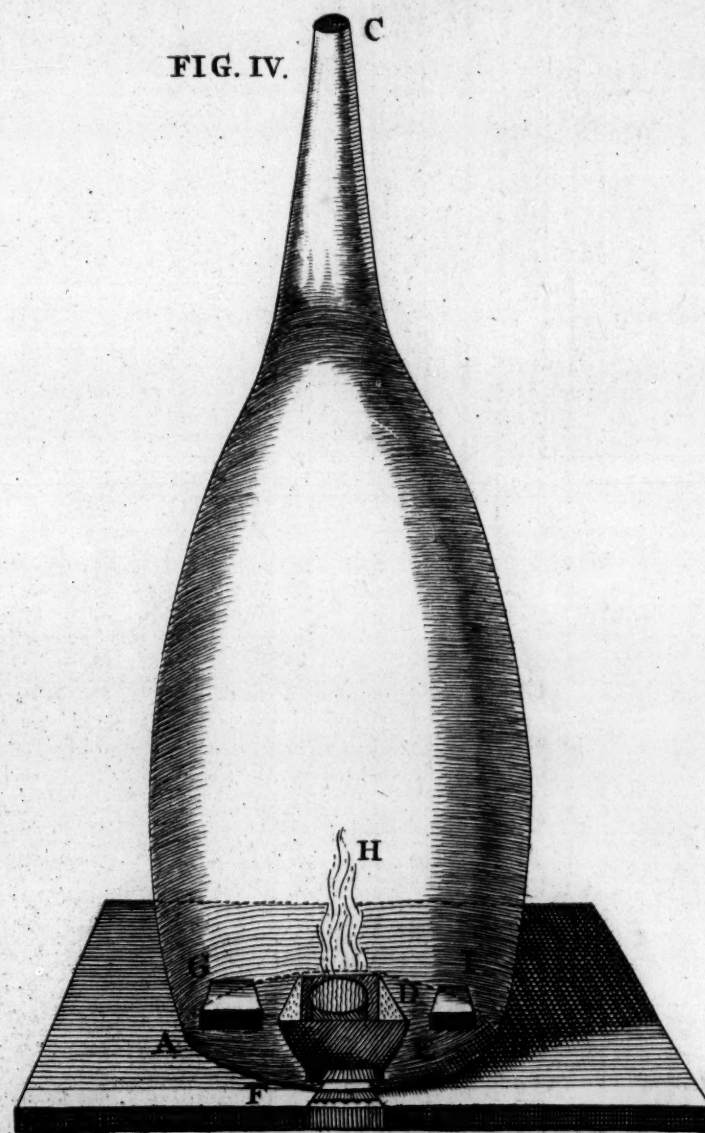


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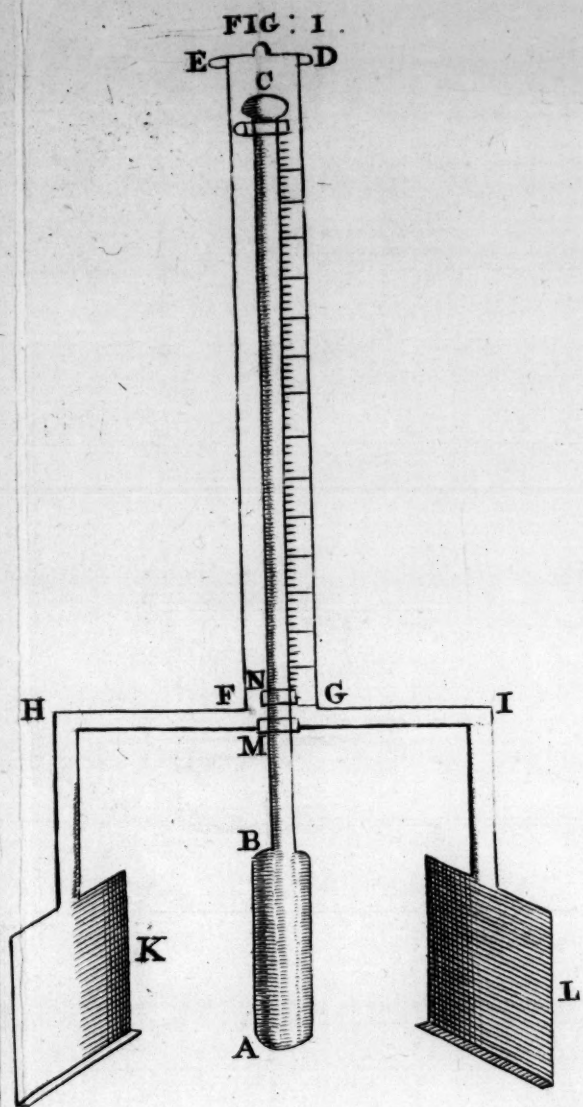


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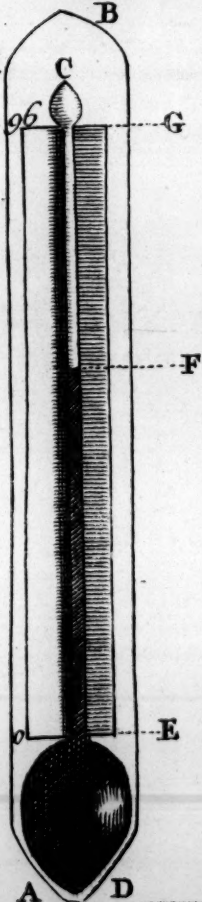


FIG. III.



PLA. V.

FIG. IV.



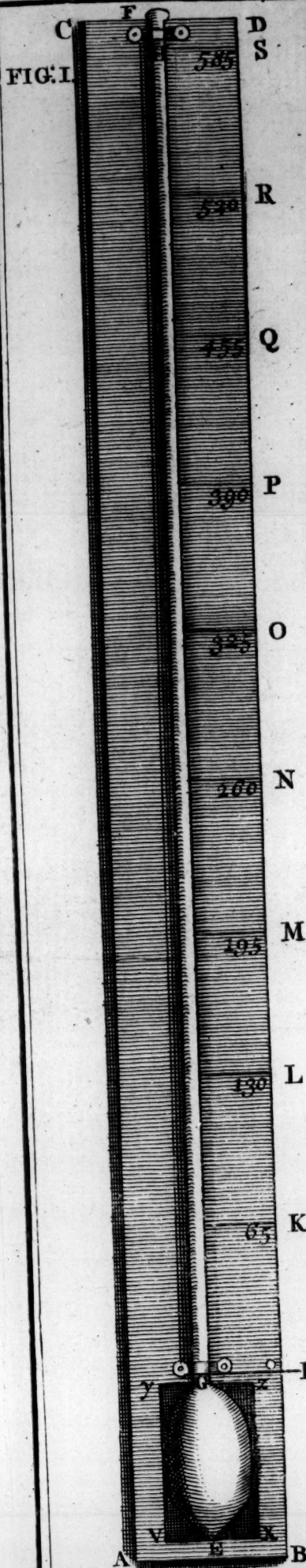
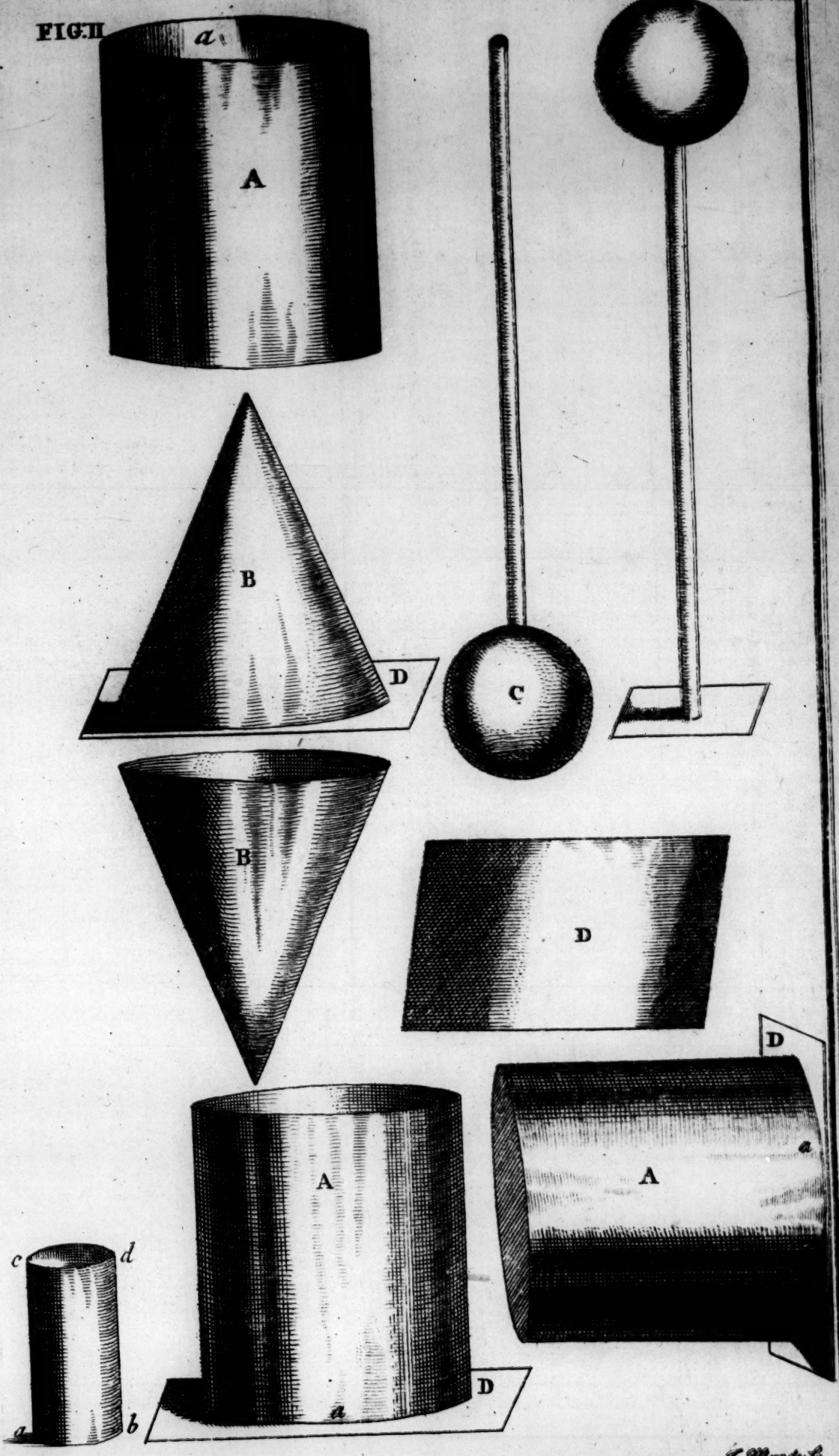


FIG. II.



J. Mynde R.

FIG. I.



FIG. II.

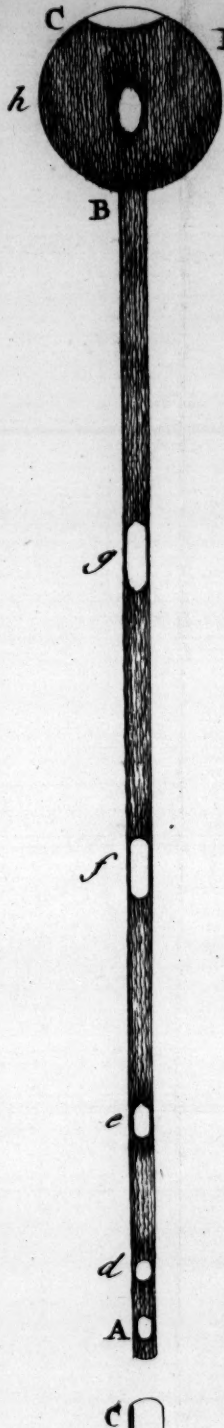


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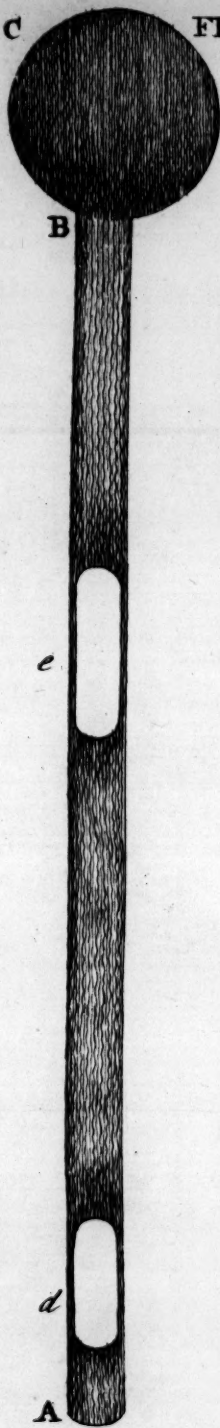


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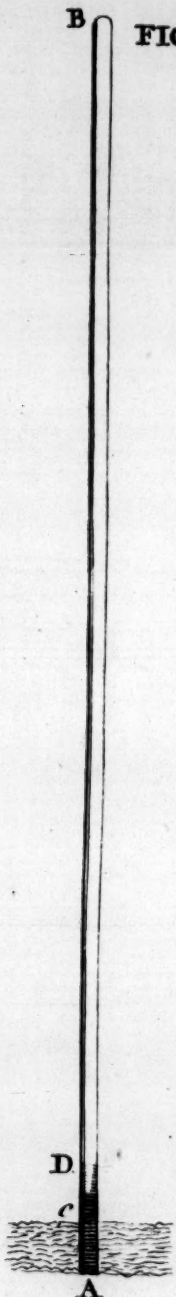
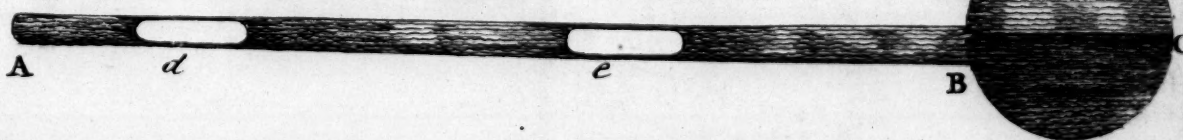


FIG. IV.



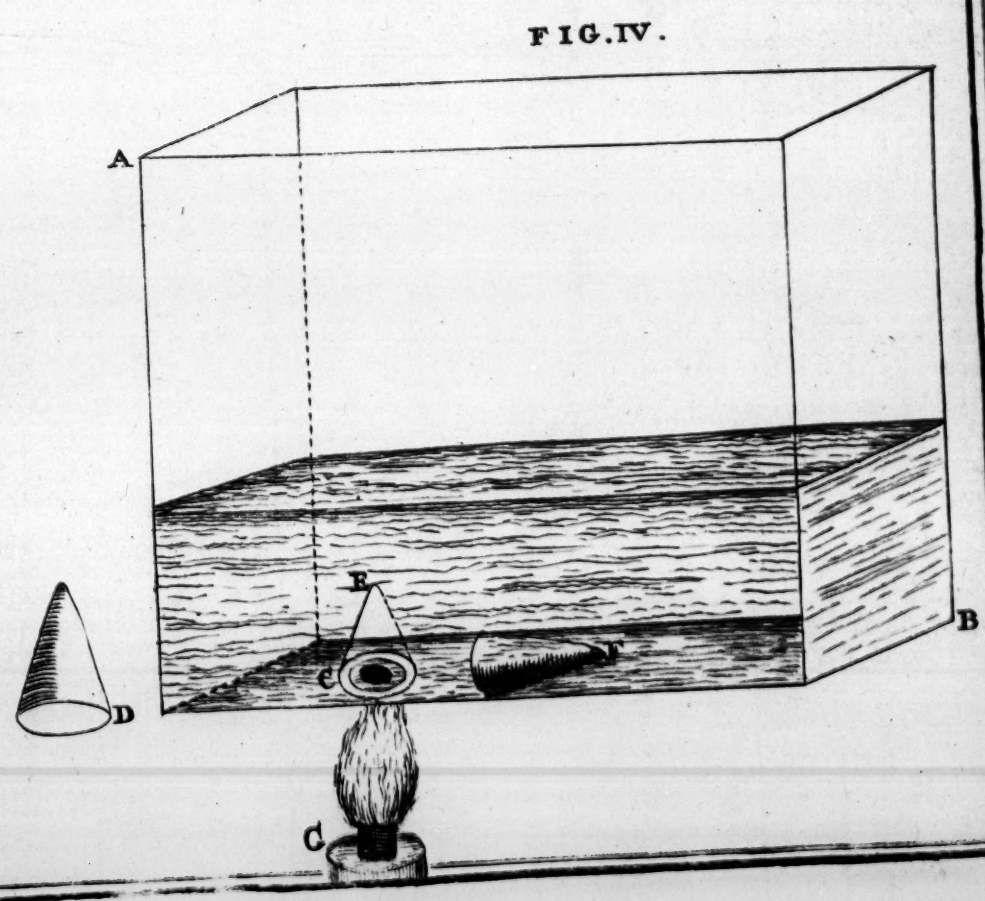
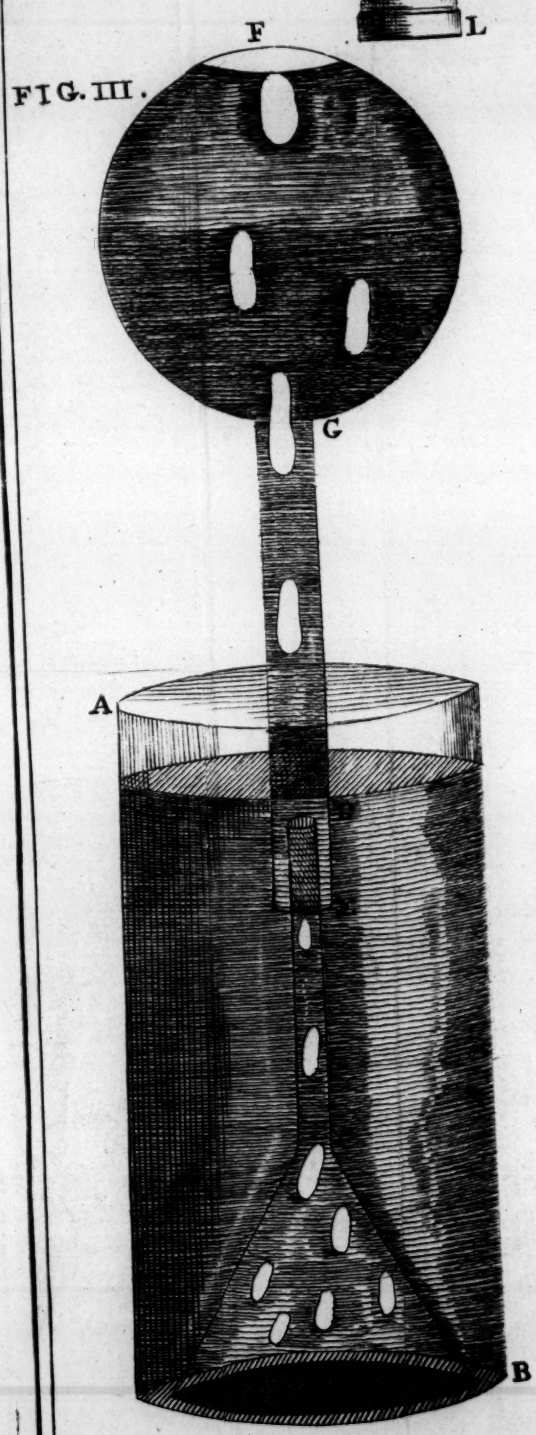
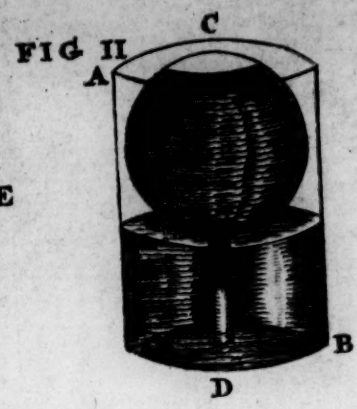
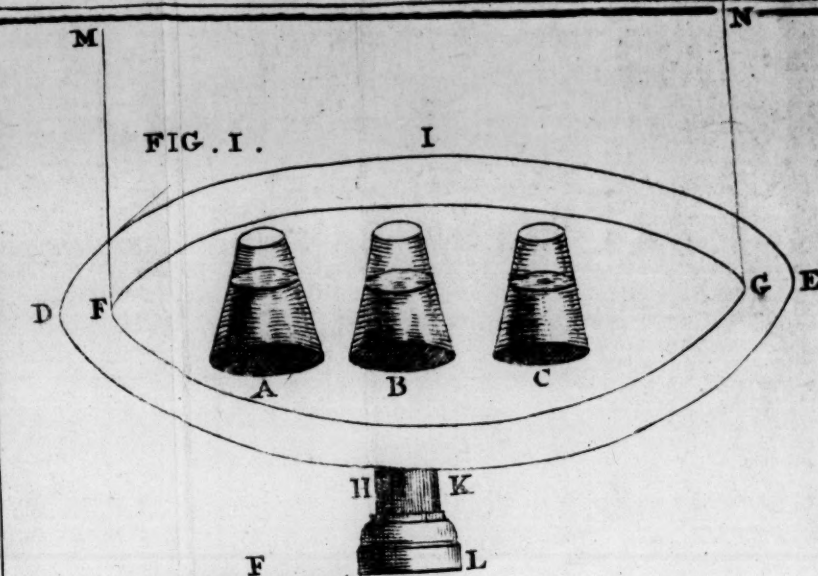


FIG: II.

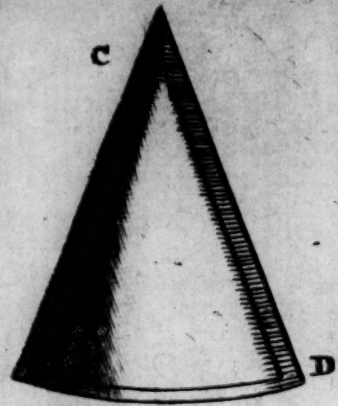
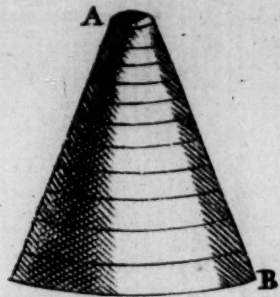


FIG: III. K H I L

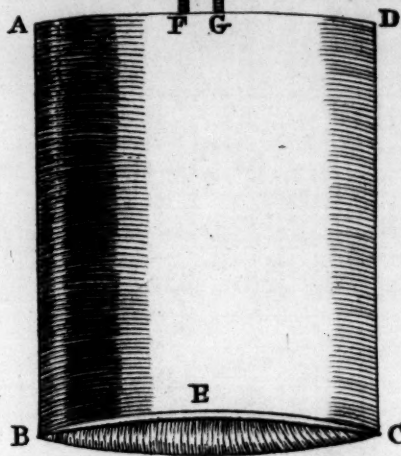


FIG: I.

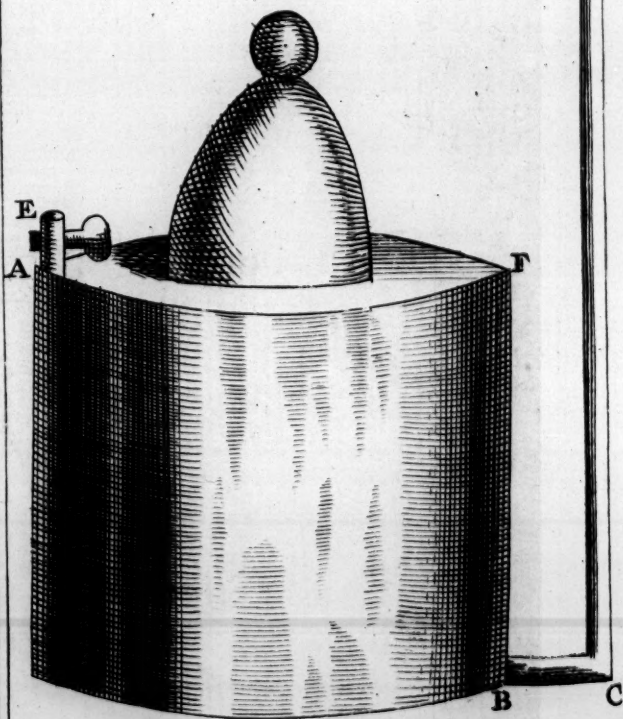


FIG: IV.

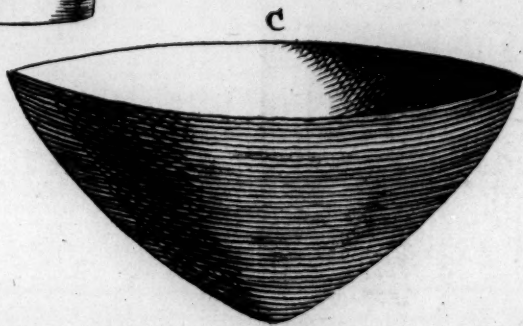
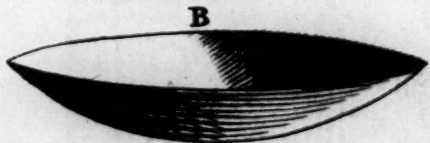
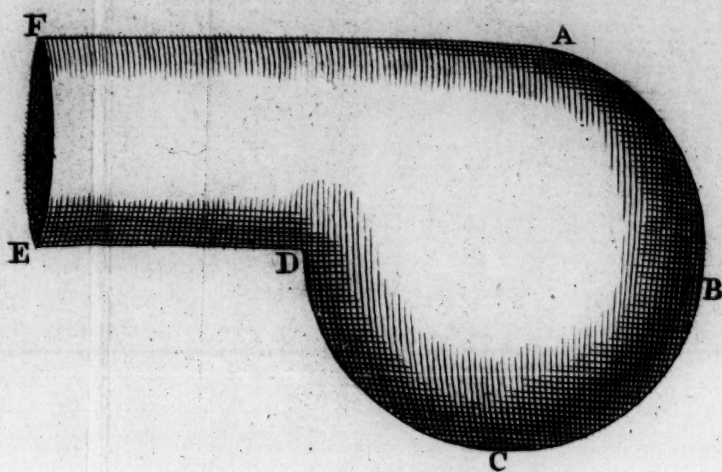


FIG. I.



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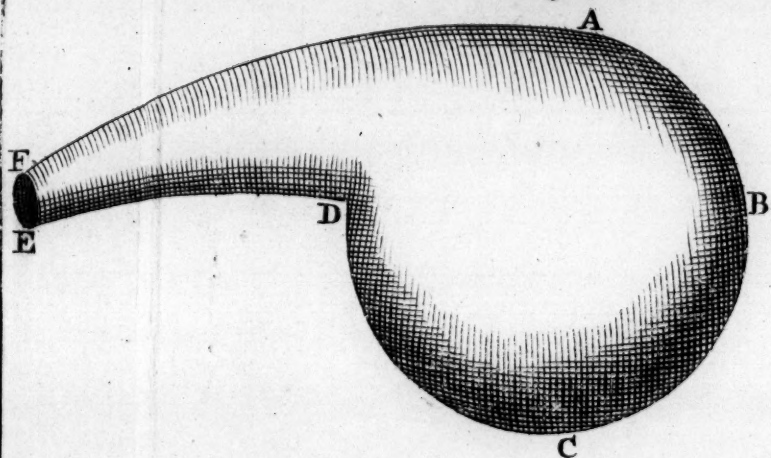
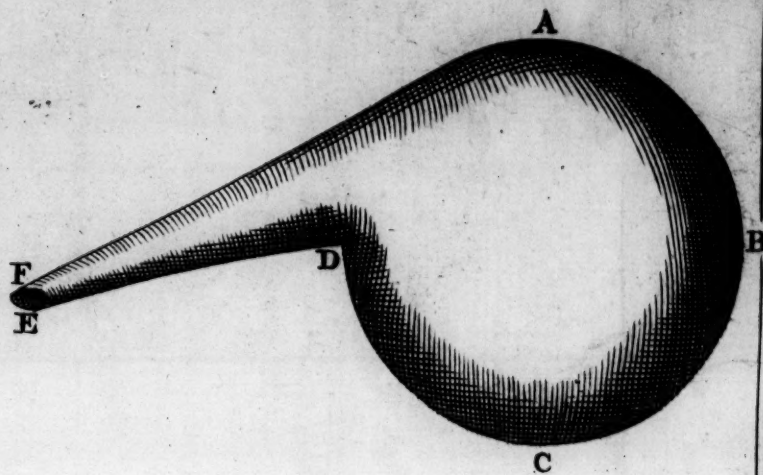


FIG. II.

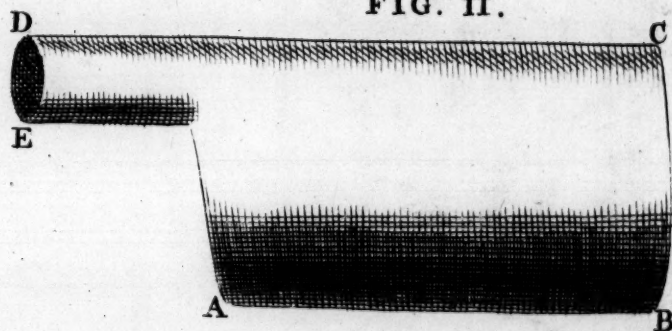


FIG. III.

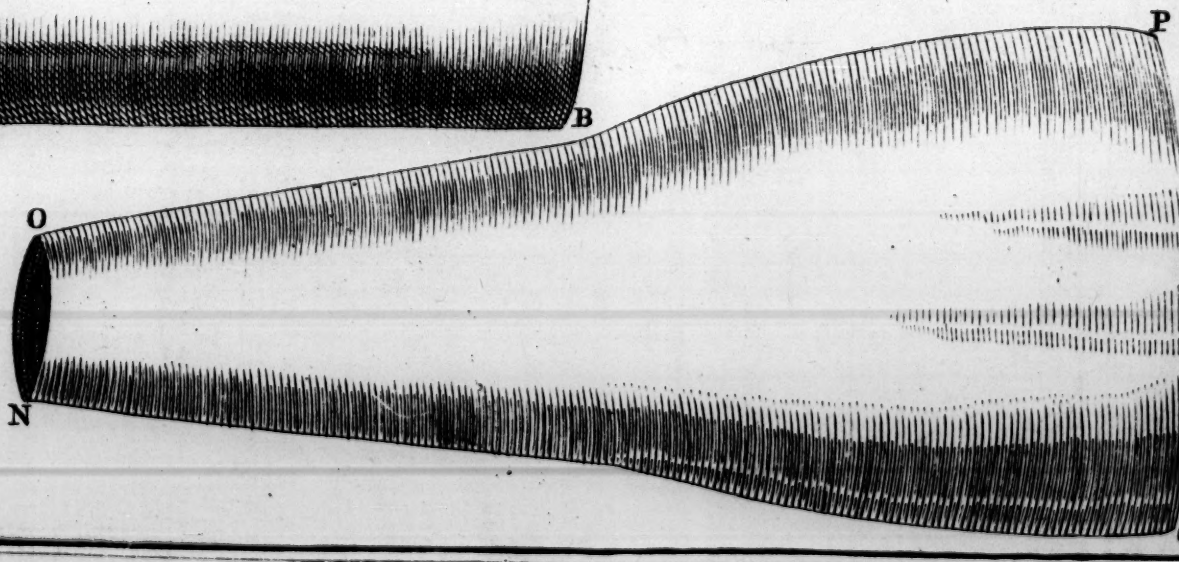
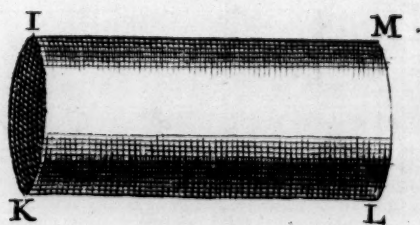
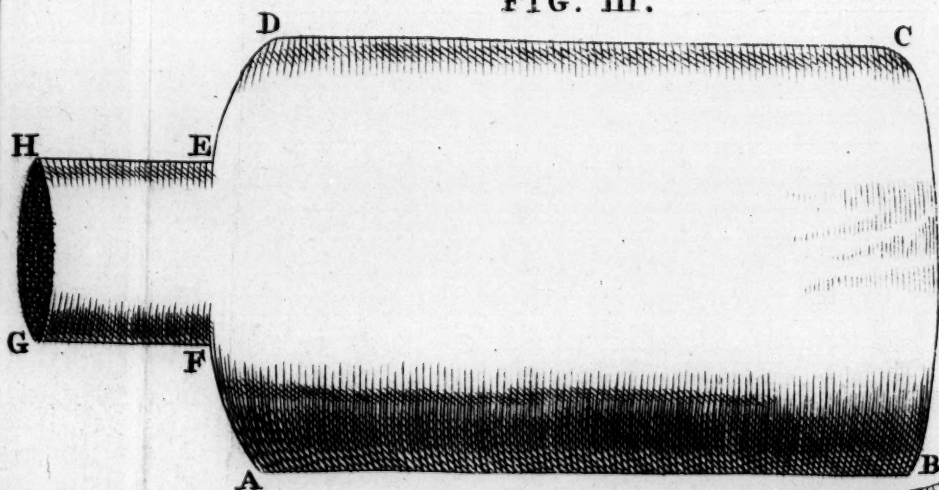


FIG. I.

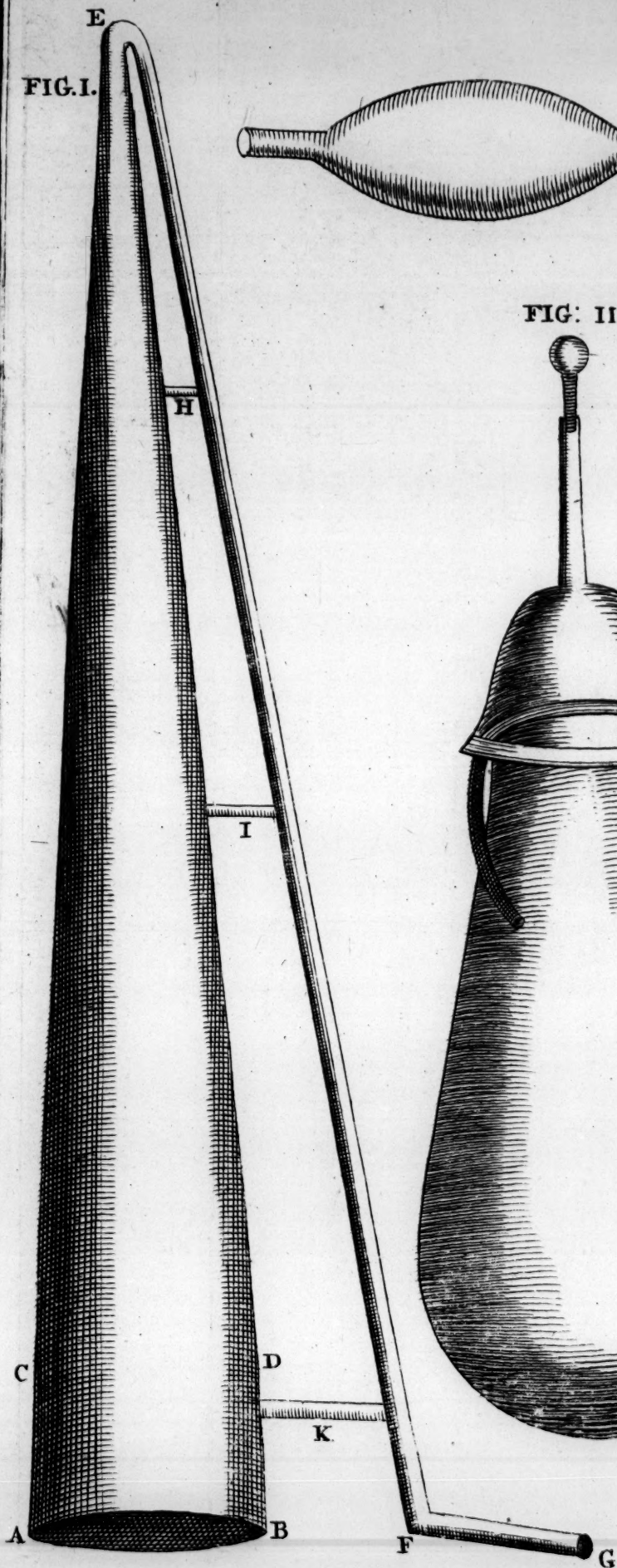


FIG. II.



FIG. III.

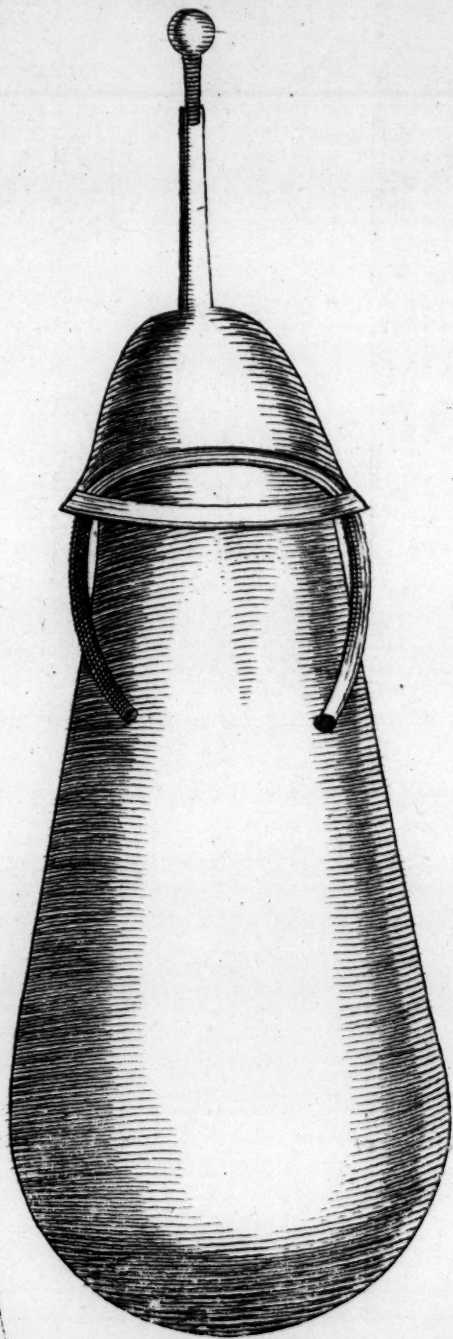


FIG. IV.

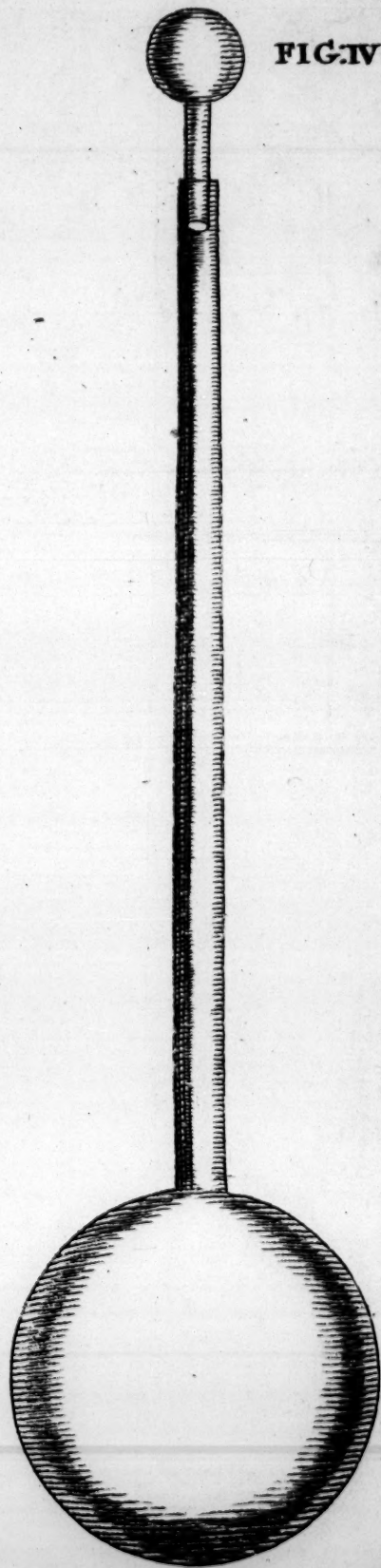


FIG. II.

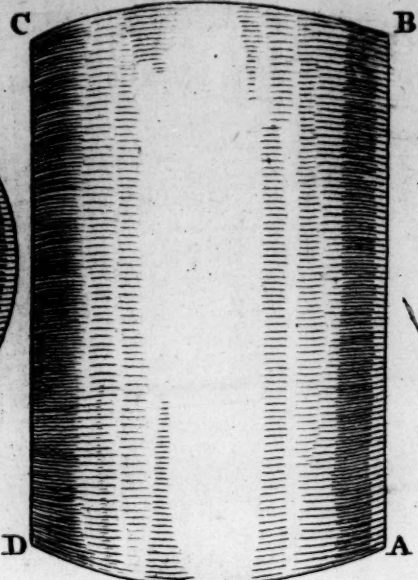
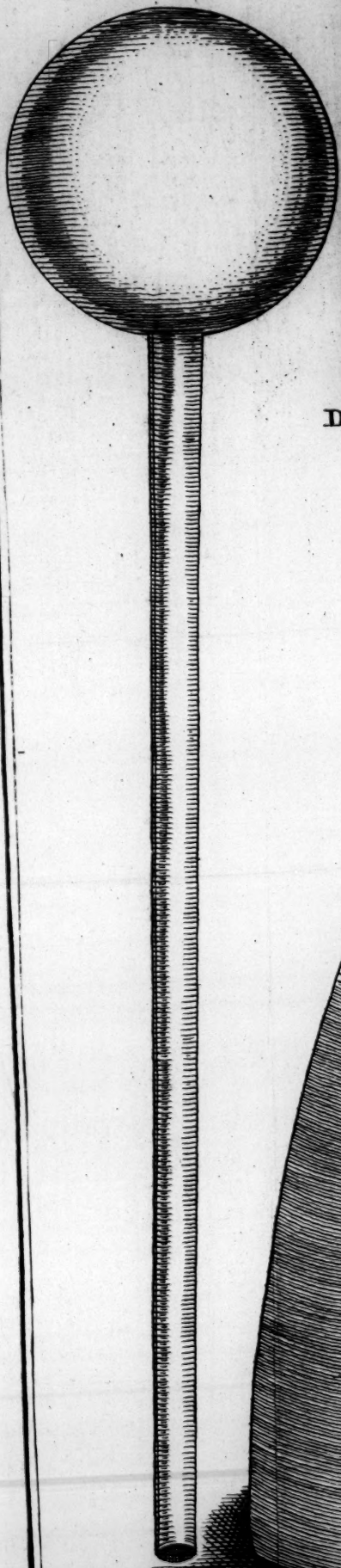
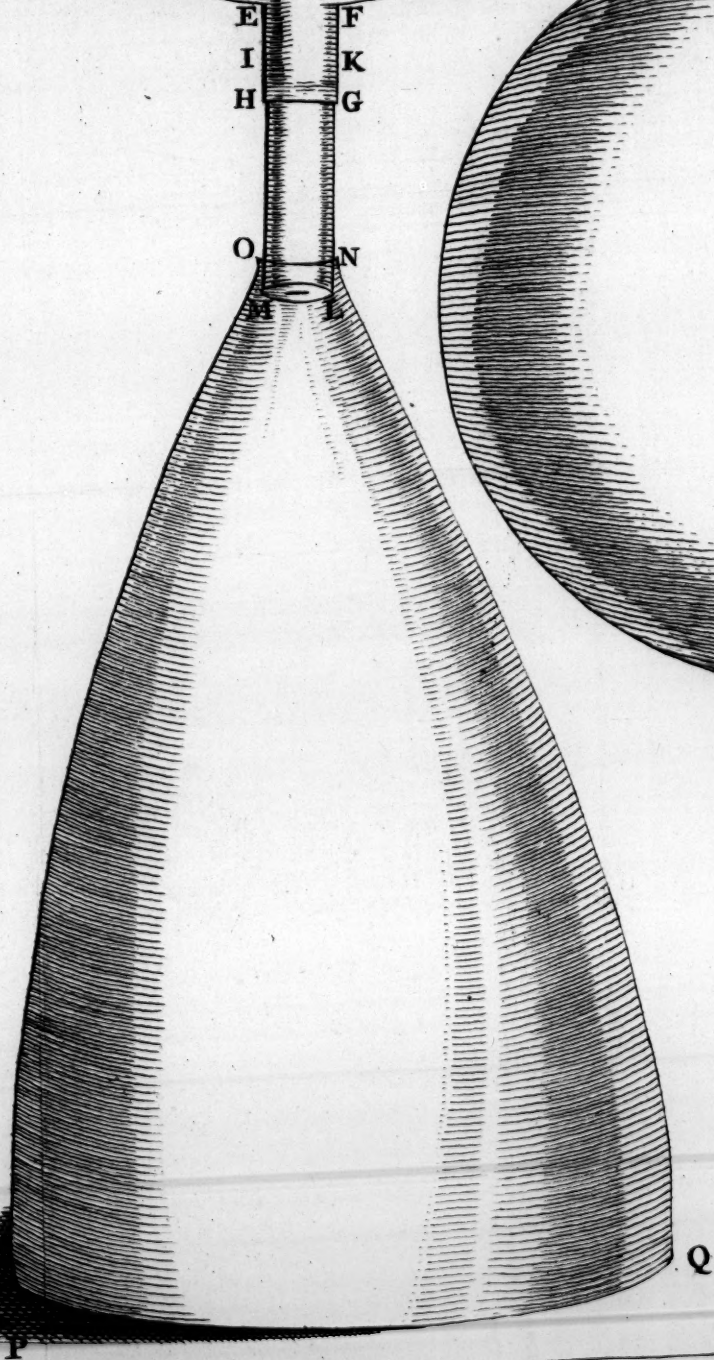
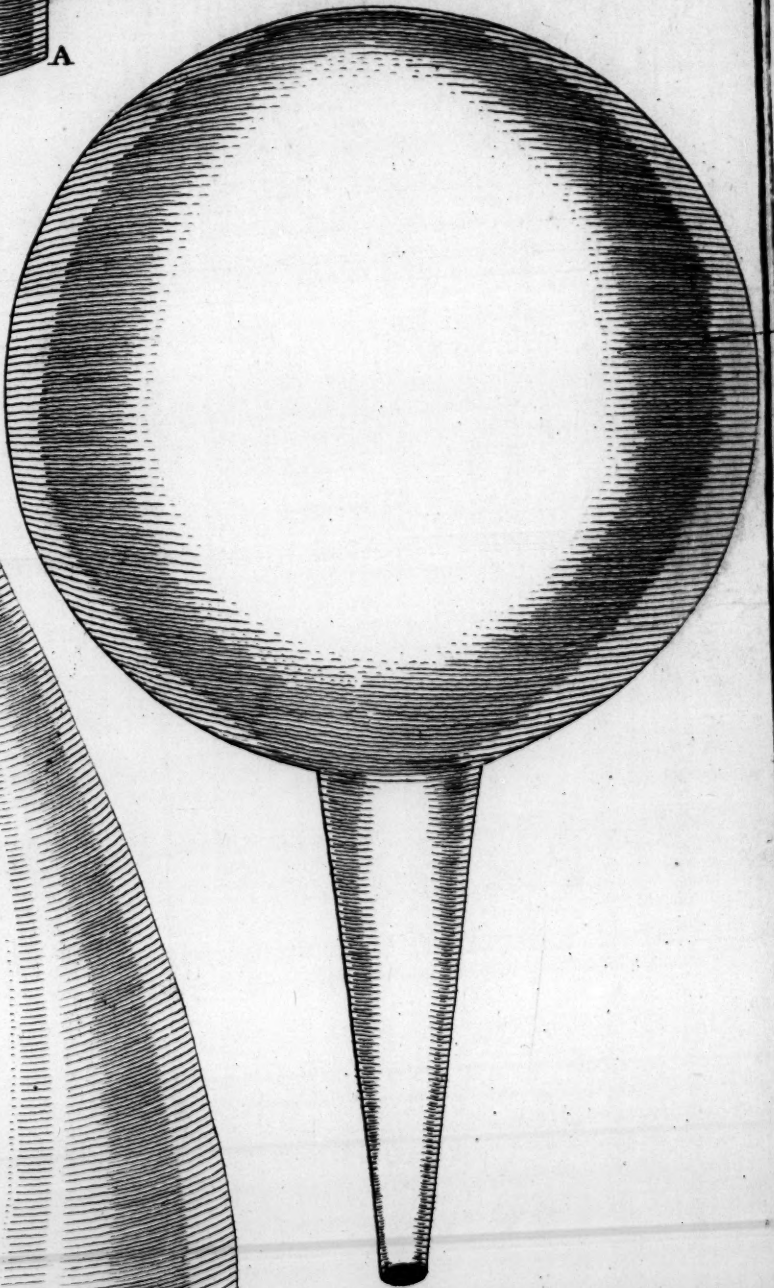
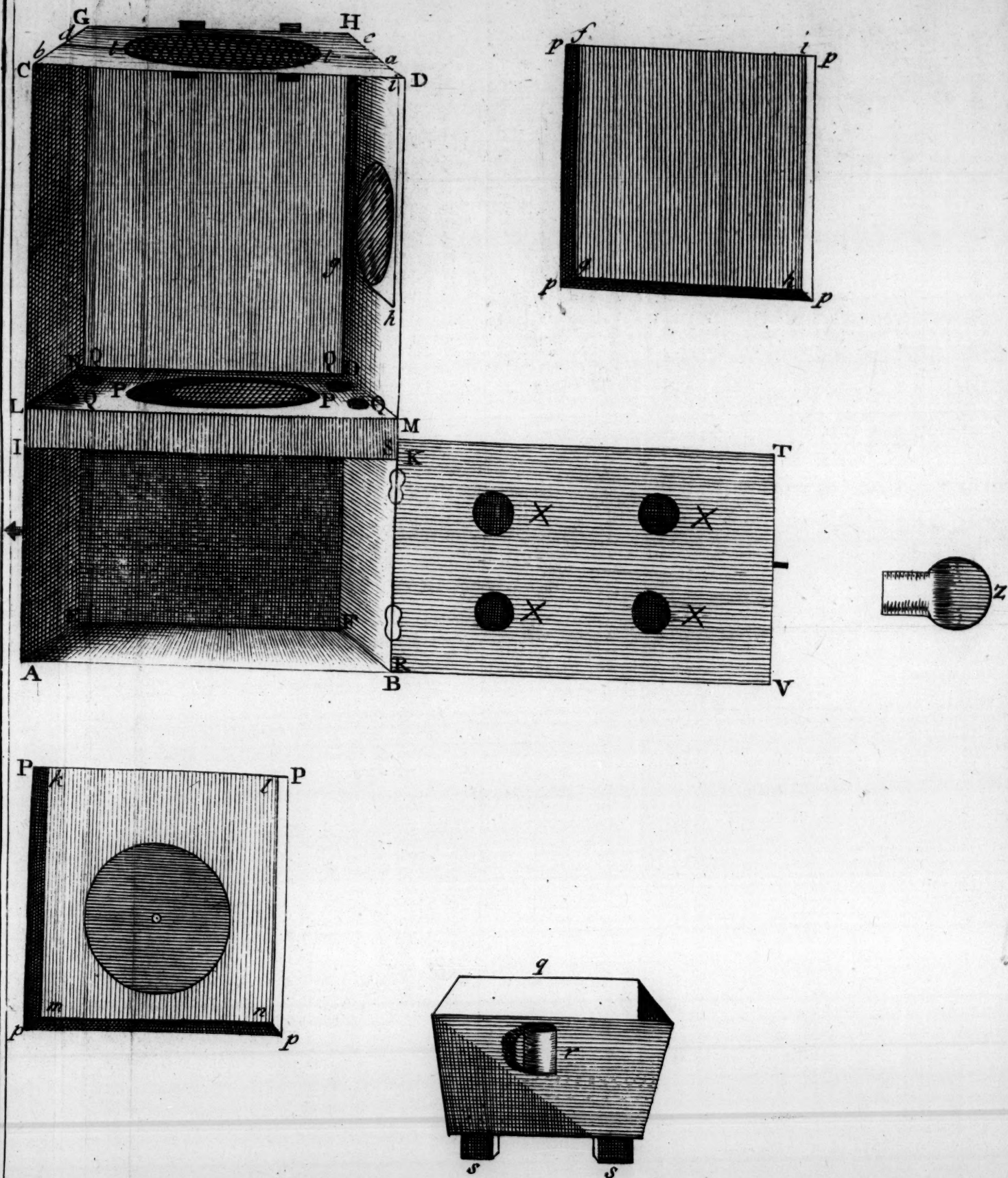
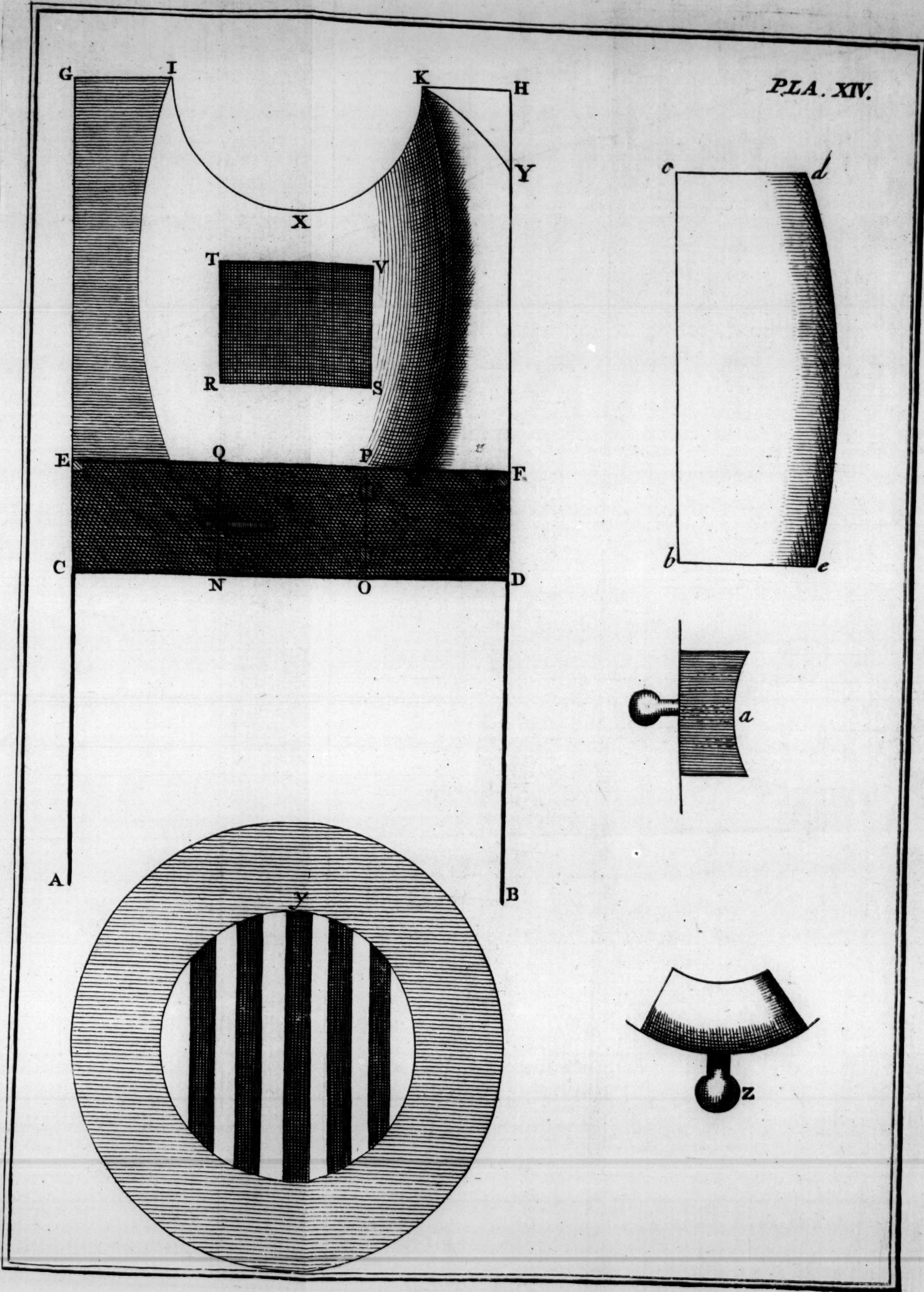


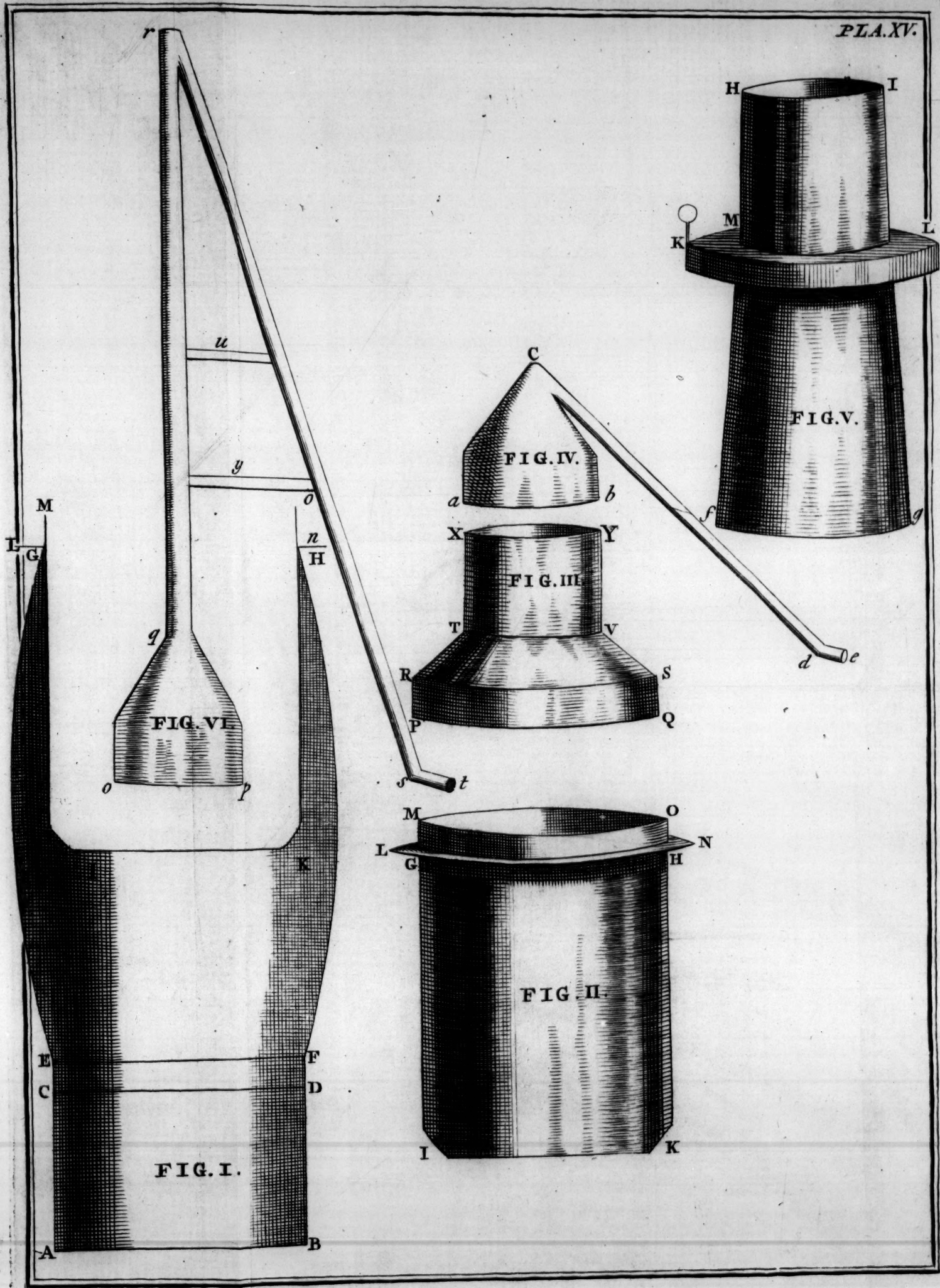
FIG. I.

FIG. III.









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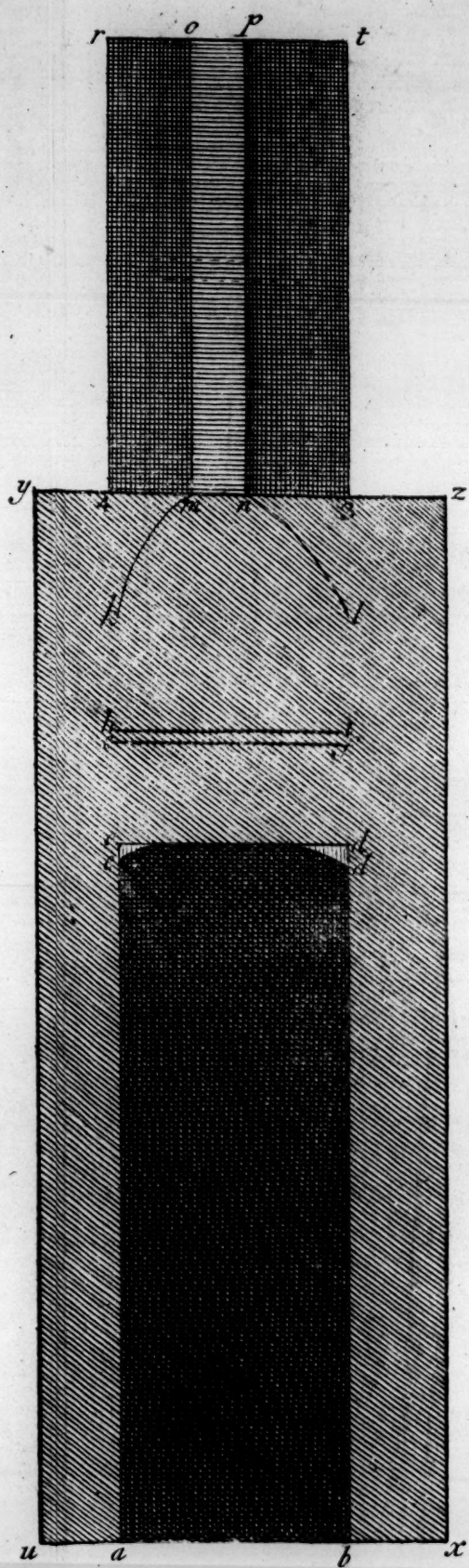


FIG. I.

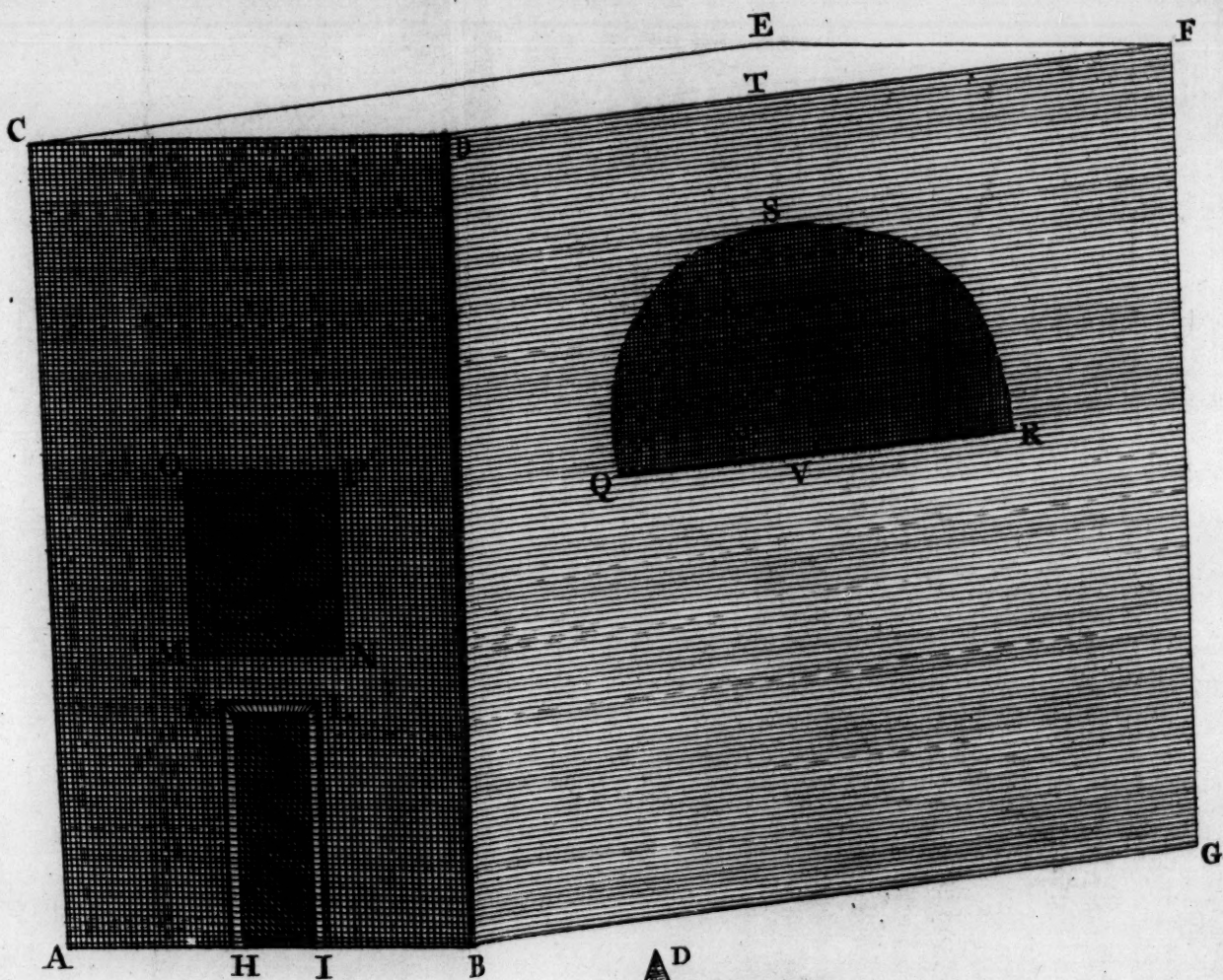
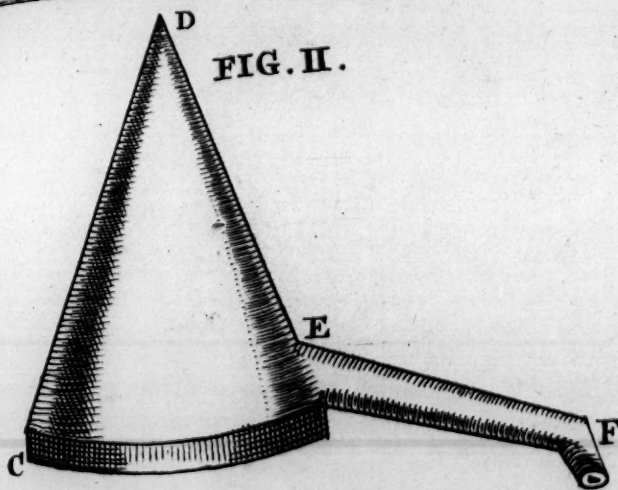
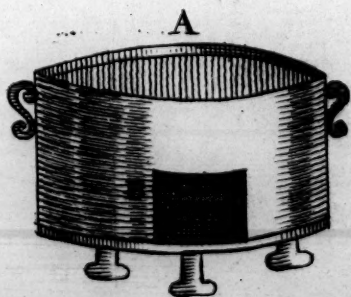


FIG. II.



I N D E X

T O T H E

F I R S T V O L U M E.

N. B. *The Numbers denote the Pages.*

A

A Cids seem to differ chiefly in the quantity of Water they contain 453. Experiments upon them with Alkali's 452. Considered as *Menstruums* 462. Native *ibid.* Vinous 434. Acetose 464. Fermenting *ibid.* By burning Vegetables 465. By distillation *ibid.* Fossil native very rare 466. Fixed frequent *ibid.* In Sulphur, Alum, Vitriol of Iron *ibid.* In Calcanthum 467. Which are all the same *ibid.* Specific Gravity *ibid.* Fossil of Nitre 468. Of Sea-salt *ibid.* *Aquæ Regiæ* 469. Corollaries concerning them *ibid.* Agreement 470. Difference 471.

Agitation perpetual in the universe from Heat and Cold 92.

Air separated from Water by an Alkali 303. expands itself in proportion to Heat 316. Hotter in vallies than in higher places 141. Different with regard to the Soil 290. A second universal instrument of nature 247. Colder than the human Body 116. Fittest to discover the quantity of Fire 97. Pure more elastic than when filled with wa-

tery Vapours 272. Attracted into the empty Interstices of Liquids 299. Contains a good deal of Gold 249. divided into different *Strata*, each of which contain different kinds of exhalations. 287. Hot and moist for a great while produces a plague 281. Generated from Oil of Tartar and Oil of Vitriol 310. From Spirit of Nitre and Iron 312. From Spirit of Nitre and Oil of Caraways 313. Adheres to Solids 294. To Fluids *ibid.* To itself 295. Elastic separated from Bodies by Fire 314. The universal Chaos of all Bodies 268. Produced from Vinegar and Crabs-Eyes 308. Condensed by Cold 267. Mixes Bodies together 315. The effects of its gravity *ibid.* A hidden vertue 292. Very corrosive in *America* 298. Don't act in Water as Air 307. Expressed out of Water by Frost, and collected makes Ice light, and rare 360. Not very penetrating itself 307. What it does in Fossils 248. Does not enter into Water already saturated 300. Never at rest 101. Never hardned by

Y y y

I N D E X.

by Cold 249. Impregnated with Mercury will raise a salivation 288. When it contains least Water may appear most humid 272. Naturally contained in our Fluids, but so dissolved as not to act like Air 308. Contains Water on the highest Mountains 277. Most of all Bodies contracted by Cold 266. Always in a pretty rapid Motion 257. Mixes itself with almost all Fluids and other Bodies 247. Separated from Water by boiling 301. Agitated with a vast force excites heat 112. Compresses Bodies so much more as they are nearer to the center of the Earth 254. The occasion that scarcely any body is ever at rest 316. Whence it often becomes poisonous 287. Always capable of rarefaction 262. Mixes with more difficulty with Liquors than any other known Fluid 295. Warm, its surprizing effects 163. How cool it must be for a Person to live in 116. Gives Fire often a surprizing power 236. Its effect, as fluid and heavy together 255. Its Elasticity augmented by Heat 265. Its Properties, as elastic 294. Law of its Elasticity 260. Its Gravity 252. A small portion equal to the whole 264. Fineness of its parts 250. Lubricity of them 251. Attraction of them *ibid.* Contains native Spirits of Vegetables 282. Their fermented Spirits 283. Their Spirits produced by Fire *ibid.* Their Oils *ibid.* Their Salts 284. Their Earth *ibid.* Intire parts of Vegetables *ibid.* Spirits of Animals 285. Their Excrements *ibid.* Nearly all their parts *ibid.* Their Eggs *ibid.* Fossils 286. Salts *ibid.* Sulphurs *ibid.* Metals *ibid.* Weight of its elastic part 292. Separated from Water by Frost 322. Out of a hot animal Liquor 303. Its quantity in Water greater than the Water itself 306.

Alcahest 489.

Alchemy 9. Authors 10, 17. First Professor *Paracelsus* 13. Assisted by Chemistry 72.

Alcohol extinguishes Flame 186. Feeds Flame 187. Produces the purest Flame 188. Burnt, yields a watery Vapour 189. Its Vapour when boiling takes fire 192. Burnt, with Water 195. With Camphire *ibid.* With Oil 196. With the *Offa Helmontiana* 197. With Earth 198. With all the four preceding *ibid.* The one pure inflammable Body 199. When alone feeds flame *ibid.* When burnt, produces no Smoke 200. No Ashes *ibid.* No disagreeable Smell *ibid.* Tenacious of Water *ibid.* Produced only from Vegetables 201. Compounded *ibid.* Resembles Fire *ibid.* What effect would it have upon Fire, was it absolutely without Water? 202. Produces a weak Flame 204. Does it cause an effervescence with Fire, and so excite Flame? 201. Is it a magnet to Fire? *ibid.* Boils in 175 degrees of heat 429. Considered as a *Menstruum* 436. May be united with a fixed Alkali 437. What Bodies it dissolves *ibid.* Don't evaporate from red-hot Iron 153.

Alembic Pl. XV.

Alum 29. Acid Salt 66.

Amalgama like the finest Silver 403.

Amber 31.

Animals examined 40. What degree of Heat in those that have Lungs 242. Perform their vital actions within the 33d and 94th degree of Heat *ibid.* Analogy betwixt them and Plants 41, 375. Don't putrify in *Vacuo* 316. Receive their firmness from Earth 383. That eat no Sea-salt, have no fixed Salt in their Urine, or acid in their Blood 43. Instances of some suffocated by Heat 163. What parts in the Air 285. What parts yield a Pabulum to Fire 208.

Antimony

I N D E X.

Antimony 35. Butter not dissoluble in Water 338. Increases in weight by Fire 237.

Areometers, how fallacious 102.

Arsenic, different sorts 30.

Ashes of Vegetables examined 178. Some not salt 171. Pot 443.

Asia, Chemistry first cultivated there 5.

Atmosphere, its effect upon Fire 205. The nearer the Earth the hotter 104. Whence varies so much 279. How affects ebullition 104. Difference betwixt its greatest and least gravity 253. Effects of its pressure 254. Always to be regarded in describing a Chemical Operation 317.

B

Baroscopical Tube shook with Mercury produces Light 111.

Bell struck runs into Ellipses 117.

Bile coagulated by Alcohol 201. Very greedy of Water 422.

Bitumen 31. As a Pabulum of Fire 210.

Bismuth 34.

Bodies all naturally equally hot 166. Black grow hottest with the same Fire 131. White reflect Fire powerfully *ibid*.

Boles 35, 385.

Bones grow soft in Acids not in Alkali's 425. An extraordinary experiment upon calcin'd ones 344.

Brass rusts with Rain-water 340. Melted, its effects upon cold Water 173.

Brewing 72.

Bubbles, how formed in Liquids 305. Fulminating 302.

C

Carcasses of dead Animals disperse almost all their Elements into the Air 285.

Camphire a most perfect simple Resin 108. How burns *ibid*. Dissoluble in Alcohol and Oils 186.

Chemistry, the name very ancient 4. Medicinal, its origin 9. Defined 19. Objects of it *ibid*. Actions of it 44. Don't resolve Bodies into their proper constituent parts 46. Its service in

Natural Philosophy 50. Its use in Physick 52. In the mechanical Arts 56. Its Instruments 96.

Christian Greeks, the chief alchemistical authors 7.

ChrySTALLIZATION, what 333. On what depends *ibid*.

Chalybeate Waters alcalescent 351.

Chyle naturally contains Air 308.

Charcoal sends forth an invisible Fume fatal to all Animals 177. Can't be reduced to Ashes in a close Vessel 171. examined 178. Combustibility depends on its Oil 177.

Cinnabar native 25.

Clyffus, what 49,

Clouds 274.

Cookery assisted by Chemistry 70.

Cold absolute not known 91. Greatest natural observed 97. Artificial 101. Fluids, and hot mixed, the Effect 160. Greatest on the tops of Mountains 104.

Colours capital, how may be examined with regard to their power of exciting Heat 132.

Copper, its character 24.

Corals calcined increase in weight 237. yield a tincture to Wax 487.

Cotyledons of Plants abound with balsam 38.

Cupels, of what made 377.

D

Dew 273. Analysis, why so different *ibid*.

Diamonds condensed by Cold 90.

Dogs, how they so nicely distinguish Animals 285.

Duumvirate of Motion in Fire and Air 293.

Dying, art of it assisted by Chemistry 56.

E

Earth defined 364. Perfect by distillation 365. From the Ashes of Vegetables 366. From Smoke and Soot 367. In fixed alkaline Salts 369. In putrified Animals 373. And their distilled humours *ibid*. Separated from Vegetables by Putrefaction 376. Not by Fermentation *ibid*. From Animals by

Y y y 2

Com-

I N D E X.

- Combustion 377. From Salts by Solution *ibid.* Distillation 378. In sulphureous Liquids 379. Is there any in Metals? 380. Scarcely in Mercury *ibid.* Or other Metals 381. Yields a firm Basis to Bodies, and unites their other principles 383. Hinders Salts from melting 384. Fixed in the strongest Fire 365. Fixes Bodies naturally too volatile 383. Exceeded by no Body in Simplicity 365. Being mixed with Salts and Oils, is easily rendered volatile 368. Serves to purify vegetable and animal Salts 384. the purest combined with another principle, dissoluble in Water 370. That produced from Metals han't the true Marks of Earth 380. What called Virgin Earth 365. Addition of it very necessary in many chemical Operations 384. What sort fit for Tests 367. Use in production of Phosphorus 385.
- Ebullition gives Liquors their greatest heat 103. In different Liquors surprizing 105.
- Egyptians* cultivated Metallurgic-Chemistry 6.
- Egg, Yolk and White wonderful Solvents 485.
- Elixir, what 50.
- Enamelling 56.
- Experiments, why often succeed in one place but not in another 290.
- Extract, what 49.
- F
- Fahrenheit*, a surprizing experiment of his in the production of Cold 98.
- Fermentation won't produce Wine without the admission of Air 283. Don't separate the Earth of Vegetables 376. promotes the acidity of their Salts *ibid.* Changes one sort of their Oils into a volatile Alkali *ibid.*
- Fire-place and Chimney without Smoke 179.
- Fire rarifies all Bodies 84. Does it melt them into their Elements? 88. Alone perfectly unites Metals 89. Don't absolutely expel Air from any place 95. The greatest natural in the Air 96. First manner of producing it 107. Where least 110. Pure scarcely discernable 111. Pure of the Alchemists 112. And *Hebrews ibid.* Excited by the attrition of Metal against the softest Fluid *ibid.* Always present in every place 113. In every Body *ibid.* Its quantity, as the spaces it is diffused through *ibid.* Always in motion 114. Don't penetrate the substance of Bodies 115. Where greatest 119. Why quits a rare Body sooner than a dense one 120. Excited by the vibration of elastic Bodies 121. Not really generated by this means 122. Its proper tendency 123. Computation of its force and quantity 124. Determined by the Sun into a Parallelism 125. Scarcely reflected by black Bodies 131. Powerfully by white and yellow *ibid.* Not increased by any of the heavenly Bodies, but the Sun 137. Effect don't depend intirely upon its quantity 142. Catoptrical 134. Dioptrical 146. Effect of the greatest 147. Perhaps not emitted by the Sun 150. The greatest physically produced 151. United with Bodies, without any addition of Weight 154. Causes of its continuance in Bodies 156. Why extinguished by Water 157. Distributed through Bodies, in proportion to their bulk 160. An examination of its *Pabulum* in the vegetable kingdom 168. Produced by the putrefaction of Vegetables 182. How supported by its *Pabulum* 185. Extinguished by Alcohol 186. Fed by it 187. Somewhat resembles Alcohol 201. How affected by incombustible matter 204. Whence increased 205. Common explained *ibid.* Not generated from its *Pabulum* 207. Its *Pabulum* in the animal Kingdom 208. In the vegetable one *ibid.* Arising from the mixture

I N D E X.

ture of vegetable Substances 214. From the mixture of animal and vegetable Substances 220. From the mixture of fossil Substances 221. From a cold Body, by the access of the Air 222. From cold Fossils by the help of Water 225. From cold Liquors 226. Corporeal *ibid.* As extended *ibid.* As it is moveable 227. As it resists Body *ibid.* Its Corpuscles the least we know of 228. Vastly solid 230. Smooth 231. Simple 96. Always in motion 233. Do not generate Fire 234. Or are generated *ibid.* Not a universal Solvent 237. Don't divide Bodies into their constituent parts *ibid.* Nor dissolves all *ibid.* Nor divides Bodies into their simple Elements 238. Compounds Bodies 239. Acts differently with regard to Air *Ibid.* Chemical, its various degrees 241. Its action in the upper regions, perhaps scarcely any thing 119. Its ultimate known action vitrification 243. When alone, can follow the swiftest motions of the solidest Bodies, and so be collected 122. The law of the decrease of its power different, from that of corporeal qualities 244. Perhaps not heavy 119. Perhaps don't appear as Fire, without the concurrence of some solid Body 111. The same quantity in Gold as in *Vacuo* 79. Relaxes and weakens Bodies 90. No magnet to it 113. The purest 235. What happens to it, whilst with combustible matter it excites Flame 190. Flame two-fold 204. Weakest from the purest *Pabulum* 202. Fossils defined 19. In the Air 286. Fossil Glebes exposed to the Air surprisingly altered 289. Coal 31, 209. Focus of Vilet's Speculum, and *Tschirnhausen* Convex-Glasses united produce the greatest known heat 151. Freezing point not easy to determine 98. Frost congeals the watery parts of Liquids, and unites the spirituous 418.

Furnaces 508.

G.

Gas Sylvestre of *Helmont* 313. Gems natural 32. Artificial 59. Glass, art of it assisted by Chemistry 58. How made 457. Art of staining it 56. Some more expanded by the same Heat than other 87. Gold, its marks 34. How converted into a red Oil, and rendered volatile 288. A great deal in the Air *ibid.* Contains no Earth 389. Compounded of Mercury and Sulphur 382. Dissolved by no Salt but Sea-salt 486. By Mercury *ibid.* By rubbing with Water 340. By simple attrition *ibid.* Granulation, what 351. Gums 183. Gunpowder discovered by Friar *Bacon* 63. Fired at the bottom of the Sea 246. Takes Fire so soon from its blackness 130.

H.

Hail 278. Heat of boiling Water greater as it is compressed by a heavier Atmosphere 104. The intensest how instantly produced 109. Supposed to expand Liquors, not equably, but *per saltus* 168. In Bodies always from elementary Fire 235. Increases the deeper you dig 279. Increasing in one place, causes a greater Cold in others 246. Where greatest in the human Body 162. Retained longer by Bodies, as they are denser, larger, and nearer to a spherical figure 165. Natural of the Air 96. From the mixture of vegetable Substances 214. Of animal and vegetable Substances 220. Of fossil Bodies 221.

Helmont, his Life 15.

Houses strong tumble without any apparent cause 89. Green how to build 128.

I.

Ice, vast quantity produced in a cave in *France* 246. Rarer than Water, first observed by *Galileo* 359. From Water

I N D E X.

ter deprived of Air 360. That would not swim upon Water *ibid.* How Breaks Vessels *ibid.* The most perfect 361. A kind of Glafs 356.

Jet 31.

Jews Pitch *ibid.*

Insects all proceed from male and female 285.

Iron, its marks 25. Whence so suitable to the human body 383. Contains somewhat approaching to the nature of Earth 381. How rendered hardest 159.

L

Lapis Lazuli 35. *Hæmatitis* *ibid.*

Lake in *Scotland*, surprizing property 246.

Lead, its marks 23. Carries all Metals through the Test but Gold and Silver 367. Changes Spirit of Vinegar into an oily liquid 472.

Light, variety of it 232.

Loadstone 25.

Lutes chemical 507.

M.

Magic natural 63.

Magistery what 50.

Menstruums defined 386. Property of them 387. Division of them *ibid.* 397. Action of them 390, 393. Affisted by Fire 392. Examples of the various sorts 398. Causes of Solution concurring in them 402. Aqueous 417. Oily 427. Spirituous 436. Simple saline 438. Alcalious 440. Acid 462. Of neutral Salts 472. Compound saline 477. Universal, or Alcahest 489.

Melenteria, what 34.

Mercury, its Character 22. Rarity in boiling Water 106. In Winter feels colder than in Summer, though not really so 113. Contains no Earth 380. Greatly condenses by cold 101. Not affected by Alkali's 460.

Metals, their marks 20. When corroded by their proper Solvents dissoluble in Water 422. In the Air 287. Transmutation, on what principles 26.

Metallurgy 60.

Meteors 138, 142.

Misy, what 34.

Motion seems to decrease, the higher you ascend from the surface of the Earth 112.

Moon's rays collected produce no heat 136.

Myrrh wonderfully dissolved by the white of an Egg 485.

N.

Naphtha 31. As *Pabulum* of Fire 209.

Took fire by a Candle placed within a Lanthorn 246.

O.

Ochre 25.

Oil considered as a *Menstruum* 427. Of Linseed never freezes 428. Admits 600 degrees of Heat before it boil 429. Before it boils melts Lead 432. Contains Water 433. An Acid 434. Often a volatile Alkali 435. A *Spiritus Reflor* *ibid.* Essential of Plants 48.

Ormus Island vastly hot 128.

Orpiment 30.

P.

Pabulum of Fire 168. In Vegetables 170. How it feeds Fire 185. The heaviest produces the strongest Fire 203. Does not become Fire 207. In Animals 208. In Fossils *ibid.*

Paracelsus, History of him.

Pendulums grow shorter about the Poles, longer near the Equator 89. Meet with the same Resistance in hot and cold Water 324.

Petroleum 31. *Pabulum* of Fire 209.

Philosopher's Stone 76.

Phosphorus 222.

Polished Bodies, how to preserve them 434.

R.

Rain 275.

Refrigeration cause threefold 159.

Rivers 276.

Rivulet that never froze 246.

S.

Salts, quantity of Water necessary to dissolve them 335. Metallic all not Salts,

I N D E X.

- dissoluble in Water 337. Used to purify Water 350. Contain Earth 379. Experiments about dissolving them 416. *Phænomena* thence arising 420. Considered as *Menstruums* Defined 439. Alkaline fixed, their marks 440. Why called urinous *ibid.* Their Origin 441. Well known to the Ancients *ibid.* Prepared only by Fire 442. Perish again *ibid.* Not naturally in Plants *ibid.* From Pot-Ashes 443. From the Lees of Wine 445. By distillation 446. From Nitre *ibid.* From Tartar and Nitre 447. From Antimony *ibid.* Their Vertues 448. Consist of three parts 443. Attract Water 448. Perhaps Air 450. Alcohol *ibid.* Oils 451. Acids 452. Variously 454. Produce Glass 457. Difference of them 459. Incrated 460. Limits of them *ibid.* Volatile 462. Acid 465. Which called neutral 472. Sea, Fountain, Sal-Gem, 27. Acid Spirit 468. As a *Mensstruum* 473. Sal-Ammoniac 28. As a *Mensstruum* 472. Nitre 28. Acid Spirit 468. As a *Mensstruum* 475. Borax 28. As a *Mensstruum* 477. Alum 28. Acid Spirit 466. Sand common not Earth 385. With an Alkali makes Glass 457. Semi-metals 33. Silver, marks of it 24. Contains no Earth 381. Consists of Mercury fixed by a Sulphur 383. How rendered volatile 288. Smoke examined 178. Snow 277. Soot, its analysis 180. Sory, what 34. Speculum, the most powerful yet made 134. *Spiritus Rector* of Vegetables 38. Of Compound Bodies 47. Of Metals 49. Spirits, an ambiguous term 438. Native of Plants 38. Animals 42. Of Plants in the Air 282. Fermented of Plants in the Air 283. Of Nitre congealed by an artificial Cold 100. Native of Vegetables won't burn 173. Of Plants inflammable by putrefaction 182. By Fermentation 181. Acid 466. Springs 275. Sulphur 29. *Pabulum* of Fire 209. In the Air 287. Contains Water 342. When united with an Alkali, dissoluble in Water 425. A hundred times sublimed, still remains Sulphur 240. What effect upon Iron 225. Acid Spirit 466. Sun determines Fire in parallel lines, and perhaps does not emit Heat 150. T. Tartar, how formed 463. Dissolved with difficulty in Water 420. Teeth hurt by strong Acids, not by mild Alkali's 125. Tin, character of it 25. Thermometer of *Drebbelius* 94. Of *Fahrenheit*, Pl. V. VI. Thunder and Lightning 278. *Tschirnhausen's* famous Convex 144. Effects 147. V. Vegetables examined in their natural state 36. Burnt examined 172. Putrified produce somewhat inflammable 182. What parts of them in the Air 282. Volatile, acrid, alkaline, scarce any Salt in their Ashes 17. Acid yield a great deal *ibid.* Analogy betwixt them and Animals 41. 371. Vessels Chemical 500. *Vilet*, his famous Speculum 134. Vinegar, the strongest but $\frac{1}{10}$ th part Acid 219. Experiments upon it with other Liquors with regard to the production of Heat *ibid.* May cause Heat with our Oils *ibid.* Power of cooling don't depend upon any natural Cold in it 217. Produced from Wine in three days that was fastened in a Bottle to the Sail of a Windmill 469. Grew insipid, and acquired an aromatic Smell by being kept in a glass hermetically sealed 470. Its Spirit by corroding Lead becomes oily 472. Its Spirit, how procured most perfect. So

I N D E X.

So excellent a *Menstruum*, that all other *Menstruums* have hence been called Vinegars.

Vitriols 33. Acid Salt 466.

Vitrification the ultimate effect of Fire 145.

Vulcano's one possible cause of them 433.

Urine fresh mixed with various Liquors in order to discover the Heat produced 200. Putrified likewise *ibid.* Not naturally alcalious 42. Grows so by putrefaction *ibid.* Surprizing property in *Vacuo* 302. Grown thick with cold, becomes clear again with heat 419.

W.

War, Art of it 62.

Water defined 319. Always contains Fire *ibid.* Rendered impure by the Air and its contents *ibid.* Proper weight difficult to find 320. Well 321. Fluidity 322. Depending solely on Fire 323. When once fluid, its fluidity not to be increased 324. Its Elements small *ibid.* Less perhaps than those of Air 325. Very penetrating *ibid.* By Cold alone become less 327. Always in Motion 328. Immutable *ibid.* Its Elements not flexible 329. Not compressible *ibid.* Exceeding simple 330. Mild *ibid.* Anodyn *ibid.* Dissolving power *ibid.* Upon simple Salts 332. Upon compound Salts 334. Upon vegetable and animal ones *ibid.* Quantity necessary to dilute Salts 335. Don't dissolve all metallic Salts 337. Dissolves Alcohol 338. With Salt don't *ibid.* Attracts Alcohol, and deposits Salt *ibid.* Dissolves the Alcohol out of Oil, Resins and Camphire 339. Dissolves Soaps *ibid.* Air 340. Other Bodies first prepared *ibid.* Increases the weight and bulk of Bodies 341. Becomes concreted with saline Bodies 342. With Sulphurs *ibid.* With Earthy Bodies 343. With the solid parts of Animals 343. With Oils *ibid.* With Alcohol *ibid.* Does not produce every thing 345. Repulsive force, with regard to some Liquids 346. And Solids *ibid.* Rain various 347. Snow purest

of all 348. Spring 351. River 353. Pond 344. Vehicle of Aliments in Animals 356. Hot, its Vapours active 360. Heavier than Ice 359. Contains something subtler than Air 361. Wonderfully concealed where there is most of it *ibid.* A wave 362. Can it be converted into Earth? 362. Methods of examining its purity 345. How much heavier than Air 321. Makes the greatest part of the animal Fluids 42. Why keeps Tin from melting 158. When it boils, dissolves as much Salt as ever it will 416. Mixed with Alcohol, grows hot 215. With Spirit of Wine grows hot 214. Not changed by time 361. In great quantity in the Air relaxes Bodies very suddenly and powerfully 282. The higher it is, the sooner it freezes 277. Salt, how much exhales in 24 hours 323. *Thames*, and other stink and grow sweet again 353. With Thunder different from other 347. Rain in different seasons of the Year different *ibid.* May increase the strength of Fire 173. Exhaling from the *Mediterranean* 269. Its natural state Ice 356. Petrifying 352. Considered as a *Menstruum* 425. Experiments upon its dissolving of Salts 416. *Phænomena* in its solution of them 417. What Bodies it dissolves in all degrees of Heat 420. Dissolves earthy Bodies corroded by Acids 424. Not by Alkali's *ibid.* Boils in 213 degrees of Heat 429.

Wax not dissoluble in *Aqua Fortis* 486. Extracts a tincture from Coral 487. Surprisingly altered by distillation, without any separation of its parts 50.

Wine, method of making it 71.

Wind don't cool a Thermometer 116. How much the swiftest moves in a second 112. Great service of it 323.

World, Prophecy of its being turned to Glass 243. Causes of its spheroidal figure 91, 102.